YEAR BOOK

OF THE

American Iron and Steel Institute

1914

MAY MEETING, NEW YORK

OCTOBER MEETING, BIRMINGHAM

Compiled by
JAMES T. McCLEARY
SECRETARY

Published by the
AMERICAN IRON AND STEEL INSTITUTE
30 Church Street, New York

THE TROW PRESS
NEW YORK

FOREWORD

This is the fourth Year Book of the American Iron and Steel Institute.

The first Year Book gave the proceedings of the International meeting which began in New York on Friday, October 14, 1910, and was continued in Buffalo, Chicago, Pittsburgh and Washington. In 1911 the Institute held no general meetings.

The second Year Book gave the proceedings of the two general meetings held in 1912, the May meeting in New York and the October meeting in Pittsburgh.

The third Year Book gave the proceedings of the two general meetings held in 1913, the May meeting in New York and the October meeting in Chicago.

The present volume contains the proceedings of the two general meetings held in 1914, the May meeting in New York and the October meeting in Birmingham.

Mr. Howard H. Cook, Assistant Secretary of the Institute, rendered material aid in the compilation of this volume.

James T. McCleary,
Secretary.

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AMERICAN IRON AND STEEL INSTITUTE

SIXTH GENERAL MEETING

NEW YORK, MAY 22 AND 23, 1914

The Sixth General Meeting of the American Iron and Steel Institute was held in New York City on Friday and Saturday, May 22 and 23, 1914.

Following the practice of the preceding meetings, three sessions were held on Friday at the Waldorf-Astoria Hotel. The forenoon and afternoon sessions, held in the Astor Gallery, were devoted entirely to the reading and discussion of papers. The evening session, including the Annual Dinner, was held in the Grand Ball Room. As usual, the papers and discussions covered questions of metallurgical science, of business, and of welfare work.

On Friday the Secretary had a temporary office near the Astor Gallery, where members registered for the meeting and were provided with identification buttons and with programs.

The paper read by Mr. Herman A. Brassert on Modern American Blast Furnace Practice had been printed in advance in pamphlet form and was distributed before the opening of the forenoon session. Dr. Darlington's paper at the evening session on The Present Scope of Welfare Work in the Iron and Steel Industry was illustrated by nearly one hundred stereopticon views part of which have been reproduced in this volume.

At the noon recess on Friday, the members of the Institute were its guests at a buffet lunch and in the evening at the banquet.

Saturday, as usual, was devoted to informal visits of places of interest in and near New York City.

The attendance was the largest in the history of the Institute, numbering nearly five hundred.

On the nest page will be found the program of the Friday sessions, at all of which the President of the Institute, Judge Gary, presided.

FORENOON SESSION, 10:00 A. M.

Address by the President.............................ELBERT H. GARY

Modern American Blast Furnace Practice...........HERMANN A. BRASSERT
Superintendent, Blast Furnaces, Illinois Steel Company, South Chicago, Ill.

Discussion...JOHN N. REESE
General Superintendent, Northern Furnaces, Republic Iron and Steel Company, Youngstown, Ohio

Discussion.....................................ARTHUR J. BOYNTON
Superintendent, Blast Furnaces, The National Tube Company, Lorain, Ohio.

Discussion.....................................RICHARD V. MCKAY
Superintendent, Blast Furnaces, Pennsylvania Steel Company, Steelton, Pa.

Discussion...EDGAR S. COOK
President, Warwick Iron and Steel Company, Pottstown, Pa.

The Importance of the Investment Factor in Sales Policy...THOMAS J. BRAY
President, Republic Iron and Steel Company, Youngstown, Ohio.

Discussion.................................C. SNELLING ROBINSON
Second Vice-President, Youngstown Sheet and Tube Company, Youngstown, Ohio.

Discussion...................................HARRY D. WESTFALL
Vice-President, LaBelle Iron Works, Steubenville, Ohio.

AFTERNOON SESSION, 2:00 P. M.

The Practical Importance of Heat Treatments in the Steel Wire Industry......................................JOHN F. TINSLEY
Superintendent, South Works, American Steel and Wire Company, Worcester, Mass.

Discussion...JAMES W. SMITH
Factory Manager, The Wyman & Gordon Co., Worcester, Mass.

Transportation....................................J. FRED TOWNSEND
Traffic Manager, National Tube Company, Pittsburgh, Pa.

Discussion.......................................DELOS W. COOKE
Vice-President and General Traffic Manager, Erie Railroad Company, New York.

Recent Progress in the Building of Large Steam Turbines..FRANCIS HODGKINSON
Engineer, Westinghouse Machine Company, East Pittsburgh, Pa.

Discussion...HENRY G. STOTT
Superintendent, Motor Power, Interborough Rapid Transit Company, New York.

Some Recent Developments in By-Product Coke Ovens..WILLIAM H. BLAUVELT
Consulting Engineer, Semet-Solvay Company, Syracuse, N. Y.

Discussion.......................................CARL A. MEISSNER
Chairman, Coke Committee, United States Steel Corporation, New York.

EVENING SESSION, 7:00 P. M.

ANNUAL DINNER

Present Scope of Welfare Work in the Iron and Steel Industry..............................THOMAS DARLINGTON, M. D.
Secretary, Welfare Committee, American Iron and Steel Institute, New York.

Discussion...............................SIDNEY MCCURDY, M. D.
Chief Surgeon, Youngstown Sheet and Tube Company, Youngstown, Ohio.

Impromptu Remarks in response to call of Judge Gary

Remarks by the President.............................ELBERT H. GARY

ADDRESS OF THE PRESIDENT

Elbert H. Gary

Chairman, United States Steel Corporation, New York

Again it is my pleasure and honor to welcome to our annual meeting the members of this Institute. The meeting promises to be notable, not only for the very large attendance but also for the literary and scientific papers which will be offered. When you consider the number of the members and the work which is being done and the benefits which we are deriving from our association, I think we may say it is worth our while to belong to the Institute and to present ourselves at the meetings. Our membership now is over twelve hundred, and it is increasing. It seems that this Institute promises to be one of the most influential organizations in this country and perhaps of any other single country. That you are cordially supporting the Institute entitles you to expressions of gratification from the officers, and in fact from everyone who is interested in it.

The papers which will be read during the day will, in many respects, be extraordinary, and they will be valuable; and I think I am justified in saying to those who are contributing, that they will receive due reward for devoting so much time and attention to the preparation and the presentation of these papers. They are making a record of their work which will be enduring and to which they and those who come after them may point with pride and satisfaction.

The Temptations of Hard Times.

In times of prosperity it is very easy for us to be generous in our treatment of all the questions which are presented to us for consideration and determination. In such times it is not difficult for us to be generous to our employees and towards one another. If our mills are running at full capacity and our earnings large, and our balances in the

bank entirely satisfactory, it is natural for us to pay large wages and to deal kindly towards each other, avoiding doing anything that is unfair, giving every opportunity to inspect our mills and to know what we are doing to secure the greatest economies, and, in fact, to permit each other to know the names of our customers and even the bookings which we have; and there have been times when this generosity has been shown in a marked degree by those who are connected with this great industry. But when the orders on our books are small and the prices are low, and the demand much below capacity to supply, we are all more or less inclined to be selfish. Possibly some of us are forced to do everything we can to secure orders and to take care of our own interests, regardless of the rights and interests of our competitors in business, and also, sometimes, without regard to our obligations to our employees.

Six Months Nearer the Dawn.

Without intending to emphasize the conditions which obtain at the present time, I would be less than frank and truthful if I failed to admit that business is not as good as we would like to have it. I would like to say just what is in my mind concerning this subject, but perhaps it is unnecessary. I said six months ago, at our semi-annual meeting, that, in my opinion, we were approaching the dawn of prosperity. Well, gentlemen, don't forget that we are six months nearer the dawn. (Applause and laughter.)

But in times like these, I ask you to consider not only the propriety, but more than that, the pleasure of being fair, reasonable and generous in our treatment of our employes and our treatment of one another. It is not necessary at this time to speak of being generous to our customers, for they are taking care of themselves. (Laughter.) But it is necessary to be very considerate of each other, and it is not only our duty, as members of a fraternity who have established a reputation for fair and honorable dealing, to be very careful not to do anything that is unjust towards each other, but it pays in dollars

and cents to occupy and to pursue that course. There is no one man or company so capable, intellectually or otherwise, that he or it can afford to ignore the rights of others.

I am dealing in generalities and without any intention to refer to any individual or any company. We are all on the same basis. We are all trying to take care of ourselves but we should all, at the same time, have a disposition to try and help one another.

Some Favorable Indications.

There are some favorable things to be considered. In the first place, as is our habit, we point to the crops of the year. They are something that cannot be taken away from us, even by the politicians. The crops are growing. We are going to have an abundance this year, and they will have their influence on the business conditions of this country. We shall see improvement. This country is just as big as it ever was; it is growing just as fast. It is rich, and it is bound to be prosperous. Depressions are temporary. If we are careful of our business, if we husband our resources, if we have patience, courage, persistence, we will come out in the end all right.

But there is another thing I believe more important. As I read the signs of the day, there is a well developed sentiment throughout this country in favor of giving business—even big business—a fair chance. (Applause.)

Hereafter the statesman occupying or accepting candidacy for political office will be popular if he has the disposition and the courage to insist that there can be no contentment or acquiesence on the part of the masses of the people unless they believe everything reasonable is being done to promote and maintain material growth and prosperity. The people will not listen patiently to discourses in favor of moral uplift unless at the same time the necessities of life are provided. (Applause.)

The President: You are all supplied with programs giving the order of the papers and discussions and the

authors thereof. The program also shows the position occupied by each of these gentlemen, thus indicating his competency to speak on the subject. In order to save time, the Chair will ask each of the authors in succession to come forward to the platform and read his paper without further introduction.

MODERN AMERICAN BLAST FURNACE PRACTICE

HERMANN A. BRASSERT

Superintendent of Blast Furnaces, Illinois Steel Company, South Chicago, Ill.

The trend of development in the manufacture of pig iron is much the same the world over. With more and more difficult raw materials, progress is not so much in the direction of new records of production and fuel consumption, as in the ability to maintain the best results of the past in the face of greater handicaps. Since this paper cannot cover all conditions of raw materials and every kind of practice, I will confine myself largely to the foremost problems which the present generation of blast furnace men has been called upon to meet—the smelting of fine ores. It is hoped that this may assist in opening up a field for a wider discussion in detail of the many modes of construction and operation which form so important a part in modern furnace practice.

The present state of the blast furnace art is as much the result of practical experience and common sense as it is of science; however, the underlying principles of the process must be understood in order to appreciate its possibilities, as well as its limitations. I will, therefore, give a brief outline of the theory of the blast furnace process, and then discuss the possibilities and means of obtaining better economy, dealing first with the raw materials, next with the construction, and finally, with the operation of the furnace.

The blast furnace process for the production of pig iron is an invention of the Middle Ages. It was practiced in Germany in a primitive manner as early as the beginning of the 13th century. The first American blast furnace was built in 1644 on the shores of Massachusetts Bay. A tremendous development has taken place in the practical application since the early days, but the process, in prin-

ciple, has remained the same. The reason for its survival to the present day lies in its economy. It always has been, and is today, the most efficient of all metallurgical processes.

THEORY OF THE PROCESS.

The blast furnace performs the task of preheating the ores, reducing their metallic contents, and melting the resulting iron and slag, in one continuous process, and in the same vertical stack. The counter-current principle is employed, whereby raw materials and gases travel in opposite directions, the heat of the latter being transmitted gradually to the former, with the result that the waste gases leave the process at the point of lowest temperature, whereas the materials to be melted enter the zone of fusion highly preheated.

By the concentration of heat in a comparatively small area in the lower part of the furnace, radiation losses are small as compared to other metallurgical furnaces. Being practically constant per unit of time, for a given furnace, they decrease almost in proportion to increased output, and under modern conditions are kept well below 10 per cent. of the total heat involved. The loss of sensible heat in the waste gases is decreased to a minimum by the continuous transmission of heat from the gases to the descending stock.

Direct and Indirect Reduction.

Simultaneously with this transfer of heat from gases to raw materials, and in the same manner, the reduction of the oxides takes place. The descending ores are gradually reduced by the carbon monoxide of the rising gases, the leanest gases coming in contact with the highest oxides at low temperatures near the top, the richest gases meeting the ores in their final stage of reduction near the melting zone. Thus the largest possible proportion of the iron oxides is converted into metallic iron in the most economical way, for the reduction by carbon monoxide of Fe_2O_3 is a slightly exothermic reaction, and that of FeO, while being endothermic, requires only a small amount of heat. The

"direct" reduction by solid carbon, on the other hand, which must be applied to such portions of the iron oxides as have escaped the "indirect" reduction, is much more extravagant, requiring five or six times more heat than the reduction by the gases.

Since iron oxides are reduced by the gases in the blast furnace only within a certain range of temperature, lying between 200° and 1100° C., and since it is difficult for the gases to reach every particle in a big bulk of ore in time for proper preheating and reduction, it will be at once understood that the furnace charge must descend regularly and the contact between gases and stock must be both intimate and uniform, in order to facilitate the "indirect" reduction by the gases.

These fundamental principles have always been the same, yet there exists quite a variation in the efficiency of different furnaces in actual practice, even when working under the same conditions. An efficiently operated furnace is delicately balanced and is easily influenced by irregularities of any kind. Slight changes of temperature disturb the equilibrium between "direct" and "indirect" reduction. An increase of direct reduction consumes additional carbon which otherwise would have been available for combustion at the tuyeres, there to generate heat for the melting process, and this fuel must be replaced by charging more coke at the top. The reduction by solid carbon consumes also more heat than that by CO, which again has to be replaced by adding more fuel. The larger the ratio of coke to ore in the charge the greater the quantity of top gases per ton of iron, and the higher their temperature and calorific value, resulting in further loss of heat to the furnace.

Increased top temperature shortens the zone of possible reduction by CO, since CO_2, which is the product of this reaction, cannot exist at high temperatures in contact with carbon. Under such conditions any CO_2 formed in the reduction of ore or calcination of limestone immediately reacts with carbon, forming CO and resulting in lowering the ratio of CO_2 to CO in the gases, and in a further loss of carbon to the generation of heat at the tuyeres. This ex-

plains why such a large excess of fuel is generally required to bring a cold furnace back to a normal condition.

The top temperature, therefore, in conjunction with the ratio of CO_2 to CO in the escaping gases, is a true indicator of blast furnace economy. The higher this ratio, the more efficient the reduction process. Low top temperatures go hand in hand with high CO_2 : CO ratios, and high top temperatures with low ratios.

Successful Practice.

The success of a blast furnace operation is measured by three results—quality of product; rate of output; and economy of operation. The first step towards their attainment is the realization that they can be accomplished by identically the same practice, the keynote of which is uniformity and heat concentration. If a blast furnace man strives for a uniform operation, giving the highest production combined with the lowest fuel consumption, he will also obtain the best grade of iron. The incessant struggle for uniformity should embrace not only the raw materials, but their distribution and descent in the furnace, brought about by proper plant design and furnace lines, as well as by intelligent operation. Such efforts will result in maintaining the largest possible proportion of "indirect" reduction, which allows the maximum amount of the carbon charge to be burnt at the tuyeres, and gives the highest hearth temperature, which means the best grade of iron. The escaping top gases will then have the lowest temperature and the highest ratio of CO_2 to CO, and will approach the ultimate economical limit, which is reached when the CO_2 : CO ratio becomes so "high"—i.e., the gases so lean—that they have lost their reducing power; or when the top temperature has been decreased to a point where the ores are not properly preheated for the reduction and melting process. This limit is determined by the reducibility of the ores. How closely it can be approached in practice on various grades of iron depends on furnace construction, mode of operation, and their proper adaptation to the raw materials.

RAW MATERIALS.

Ore.

In most countries the manufacture of iron starts with the best ores, rich in iron, and of a favorable physical structure. Such conditions facilitate good furnace operation and favor low fuel consumption, but they also tend to retard progress. In modern times, and in all civilized countries, the supply of high grade ores has been greatly reduced, compelling the use of materials leaner in metallic content and of adverse physical character, which render good blast furnace practice much more difficult. This, however, stimulates improvement, and today ores are economically smelted which were formerly discarded. In fact, thanks to improved furnace construction, a general change in opinion as to the most desirable materials is taking place; and while formerly coarseness was considered an indispensable quality, we now object to large lumps and prefer granular ores, as they allow the closest contact between their metallic contents and the furnace gases, and therefore can be reduced with a minimum expenditure of fuel.

Very fine ores are undesirable because too large a portion is carried over with the gases, increasing the loss. They also make the stock column too dense and induce channeling of gases, with the result that part of the ores are not properly prepared before reaching the melting zone, and part of the gases reach the top of the furnace without having fully exerted their reducing power or given off their sensible heat. Fine materials also tend to adhere to the walls of the furnace, and result in scaffolding, hanging, and slipping—symptoms familar to every furnace man who has used Mesaba ores.

These conditions are sometimes aggravated by the dissociation of CO, induced by the presence of finely divided oxides of iron in the upper part of the furnace. The result of this reaction is a deposit of fine carbon upon the ore charges, causing them to swell and increasing the tendency of the furnace to hang.

Too much importance, though, has been given to this

phenomenon, especially in foreign literature. We have sufficient proof that is does not take place, to any marked extent, in a normally driving furnace. In Lake ore practice, the color of the gases escaping from the furnace top during slips is a clear, reddish brown; black smoke, showing the presence of finely divided carbon, issues only after protracted periods of hanging. Furnaces using the highest percentages of Mesaba ores will run along for many months without ever showing any sign of carbon deposition, so that this reaction evidently has no bearing on the economy of the process.

Fine ores can be worked to the best advantage when they are delivered to the furnace in a state of physical and chemical uniformity. The United States Steel Corporation has made wonderful strides in this respect by developing a system of mining, sampling, grading and mixing of its ores, which has resulted in a remarkable uniformity of the various shipping grades. This is the more admirable considering the great variation of the physical and chemical character of the ores contained in the same mine.

As an example of the fineness of burdens carried at the present day, the following is a table giving the results of sieve tests on all the ores shipped to the South Works of the Illinois Steel Company during the season of 1913:

Ores	Per cent. on Screen								Through No. 100
	%	No. 2	No. 8	No. 20	No. 40	No. 60	No. 80	No. 100	
Mesaba........	83.3	25.40	26.86	12.54	10.86	6.92	2.76	3.34	11.33
Old Range.......	16.7	30.16	30.76	15.01	8.14	4.16	2.06	2.74	7.01
Total........	100.0	26.10	27.58	12.93	10.51	6.44	2.56	3.23	10.69

The suitability of any iron bearing material for blast furnace use depends on its physical form as well as on its degree of oxidation. Large lumps, even of easily reducible ores, are objectionable, because they reach the melting zone improperly preheated and reduced only on the surface. The same materials, which, if charged in the form of lumps, cool

off the hearth, can be used to good advantage if properly crushed.

With increasing fineness of the ores, on the other hand, it appears more and more desirable to render the burden more open by preliminary treatment of the finest materials.

Considerable is already being done in this regard by sintering and nodulizing the ores, and much will undoubtedly be accomplished in the future. By the addition of such pre-treated materials the physical character of the entire charge can be greatly improved. The first step in this direction is to treat the flue dust instead of recharging it in the raw state.

Briquettes of flue dust and ore are made on a large scale in Europe by a number of well known processes. In this country their introduction has been slow. The difficulty is to make them sufficiently strong, yet not too dense, and without introducing undesirable elements as binder.

Sintering, by the down-draft process, and nodulizing in a rotary kiln are practiced to excellent advantage on flue dust. They give a product of considerable physical strength and great porosity, which is easy to reduce if agglomerated without melting. A rotary kiln, treating about half of the flue dust produced, has been in operation at the South Works of the Illinois Steel Company for the past eight years. Its nodules of uniform size, rich in iron, and pre-reduced in the kiln without being melted, have proved beneficial to the furnaces even when running on the lowest coke consumption.

As the ores become leaner in metallic contents, the gangue gradually increases, until it may become an economical necessity in order to save transportation charges, to locate the furnace plant nearer the ore deposits, or by treatment of the ores, to eliminate part of the gangue, which will also serve to reduce the cost of smelting.

Ores high in alumina have previously been considered very undesirable, if not prohibitive, for blast furnace use on account of the generally experienced decrease in fluidity of slags with increase in alumina contents. One of the most important of recent developments in American blast furnace

practice is the commercial use of Cuban ores, very high in alumina.

Highly silicious ores, on the other hand, will never be suited for direct smelting except in mixture with self-fluxing ores, on account of the excessive amount of limestone required to flux the silica. The silica content affects the economy of the melting process at an increasing rate, as soon as it exceeds the amount necessary to form the desired slag volume. The elimination of silicious gangue, clay, gravel, or sand by washing is conducted on an extensive scale on the Mesaba range, the largest plant being operated by the United States Steel Corporation at Coleraine, with a daily capacity of from 30,000 to 35,000 tons of washed ore. By this operation ores with 45 per cent. iron content are enriched to 56 per cent. of iron, and at the same time a silica content of 30 per cent. is reduced to 10 per cent. and less.

Another field of great promise for the future lies in the concentration of titaniferous magnetites and in their successful use in the blast furnace. It is quite possible, and the latest results seem to indicate, that slags high in TiO_2, if uniform, will offer no more serious obstacles than those high in alumina, not to mention the possible advantage of the titanium content in pig iron for foundry or other special grades.

The commercial possibility of the reclamation of ores by washing, drying, magnetic concentration, sintering and roasting, must always depend on their physical and chemical character, on the cost of power, mining and transportation, and sometimes on the value of tailings as a by-product.

Whether the ores are used in their natural state or after preparatory treatment—which in the case of concentration always involves a loss of metallic contents in the tailings—the maximum possible yield of iron from any deposit is determined by the percentage of metallic contents in the ore; and this yield would be attained by their complete conversion into pig iron without any loss in flue dust and slag. The loss of iron in the slag is a comparatively small item, and quite uniform everywhere. The downcomer loss, while showing a greater variation, can be recovered by

treating the fine dust and re-charging it into the blast furnace. Thus it is seen that the consumption of ore per ton of iron in the blast furnace is largely fixed by nature.

Coke.

The consumption of coke, on the other hand, which is an artificial product, is subject to much greater variations, and depends to a far greater extent on human skill. To manufacture a coke of the most desirable quality and to develop the most suitable furnace lines, are today the two foremost tasks in striving for better furnace economy.

The fuels given us by nature are poorly suited for the blast furnace. In remote times wood was used. In order to obtain greater calorific intensity, this was later converted into charcoal, which, being chemically very pure, was particularly suited to the production of low sulphur iron. Rapid deforestation, however, compelled the introduction of coal as a blast furnace fuel as early as the beginning of the 18th century. The scarcity of proper coals, and the tendency, even of the anthracites, to crush and crumble in the furnace charge, led to the coking of the coal. The resulting artificial product was soon found to be superior, and rapidly replaced the use of even the best anthracites.

The coking process was at first conducted in bee-hive ovens. While capable of producing a coke of satisfactory quality, the bee-hive process is very uneconomical, on account of wasting the coke oven gases and their valuable by-products as well as part of the fixed carbon of the coal charge. Its lack of economy and its limitations to certain grades of coal led to the development of the modern by-product oven, which affords the possibility of using a greater variety of coking coals; and owing to the recovery of the by-products and the higher yield, permits the assembly of coals at the ovens, there to be mixed in proper proportions for the purpose of manufacturing a uniform and suitable blast furnace coke.

In the by-product oven a satisfactory coke can be made from coals which cannot be coked to advantage in beehive ovens, and enormous coal fields have become available for

the manufacture of metallurgical coke, largely adding to the national wealth.

Bee-hive ovens, on account of their low yield, are naturally located at the coal mine, necessitating the use of only one kind of coal, and making a product which is subject to all the variations of the coal from this particular mine. Furthermore, due to the limited supply of coal from a single mine, a bee-hive operation generally does not produce sufficient coke to supply a large blast furnace plant, so that often a number of different cokes have to be used on a furnace and the uniformity of this mixture is very difficult to control.

The by-product process is more flexible in the coking operation and is capable of improving the quality of the coke by variations of temperature and coking time to an extent unknown and impossible in bee-hive practice. By locating the by-product ovens at the blast furnace and making them a part of the furnace or steel plant, the daily co-operation of manufacturer and consumer insures the best possible furnace results.

A hard metallic structure has always been considered the first requisite of a good furnace coke, indicating its ability to resist abrasion. The crushing effect of the charges by weight is comparatively small, and the average furnace coke has many times the required strength. But the abrasive treatment to which the coke is subjected in the handling, and more so in the furnace where it is simultaneously attacked by the gases, is severe; and unless the coke is hard but not too brittle, and tough without being soft, it will go to pieces on its downward path in the furnace.

While fine, soft ores in the burden protect the coke against abrasion, the presence with such ores of coke breeze and dust is particularly detrimental by further increasing the density of the stock column and by accumulating on the walls, causing scaffolds to form. The heat value of coke dust to the furnace is practically nil, since that portion which is not blown over into the dust catcher is consumed in "direct" reduction with the ores and by the CO_2 in the gases, so that it has but little chance of ever reaching the tuyeres.

The effect of size on the vulnerability of the coke to dissolution by CO_2 is shown by the following laboratory tests, which were made at the South Works to determine the loss in weight of various kinds of coke on treatment with dry CO_2 at different temperatures:

PERCENT. LOSS IN WEIGHT AFTER BEING TREATED WITH CO_2 FOR TWO HOURS

Kind of Coke	Samples Crushed to Pass Through ½ in. and Remaining on ¼ in. Mesh at				Samples Crushed to Pass Through 80-Mesh at			
	800°C.	900°C.	1000°C.	1100°C.	800°C.	900°C.	1000°C.	1100°C.
Connellsville.	.25	.19	1.97	4.38	.20	5.00	9.70	52.80
Klondike....	.45	.84	2.90	6.50	.50	4.55	16.27	46.33
By-Product:								
No. 1......	.50	1.34	4.92	10.26	.80	5.45	15.75	40.98
No. 2......	.25	.87	3.68	9.46	.45	3.15	17.40	51.18
No. 3......	.40	.70	3.00	10.10	.50	4.20	13.00	64.60
No. 4......	.25	.83	6.10	10.14	.80	3.35	16.65	47.02

These results give an idea of the extent of the destruction of fine coke by CO_2 in the upper part of the furnace, and show the futility of charging breeze and dust into the stack with the expectation of obtaining heat value therefrom. The presence of large percentages of coke dust brings with it another disadvantage, in that it vitiates the composition of the flue dust and renders it more difficult to treat. Blast furnace coke should, therefore, be thoroughly screened at the ovens or in the furnace bins, preferably in both places, in order to obtain the cleanest possible fuel.

Careful screening is also beneficial in that it lowers the ash contents of the coke, and sometimes the sulphur, as illustrated by the following ash determinations of coke fines:

Screenings	By-Product No. 1 Ash	By-Product No. 2 Ash	By-Product No. 3 Ash
On ¼-in. sieve..........	15.28	27.05	15.74
On No. 20 sieve.....	18.66	23.30	16.10
On No. 40 sieve.......	17.11	17.80	14.00
Through No. 40 sieve	17.28	19.71	15.00
Average of Coke...	9.20	11.35	10.13

Until recent years the detrimental influence of high ash was not seriously felt in this country; therefore the washing of coals so common in Europe is still an exception here. But with leaner ores and increased cinder volume, the duty of fluxing an excess of coke ash begins to seriously increase the cost of smelting. In Lake ore practice, with 7 per cent. silica in the ores, pure stone and low fuel consumption, an ash content up to 10 or 11 per cent. in the coke represents a slag volume which is not detrimental to good practice. An excess of ash in the coke results in a threefold loss, in the shape of wasted expenditure for transportation, additional flux, and the loss of efficiency through its taking up space and heat in the furnace which should have been applied to an equivalent amount of ore.

Even more objectionable than ash is sulphur, if it exceeds a certain limit, determined by the composition, temperature and volume of the slag. These in turn are either fixed by the raw materials, or chosen to produce a certain grade of iron. To eliminate sulphur as ordinarily present, it must be dissolved in the slag, which for a given composition and hearth temperature, has a fixed saturation point, and can take care of only a limited amount of this element. In Mesaba ore practice a sulphur content of over one per cent. in the coke is very objectionable, considering the prevailing cinder volumes and the inability to obtain uniform furnace operation on very basic slags.

The problem of reducing ash and sulphur in our coking coals by dry methods or by washing opens up a wide field for profitable labor.

By-product coke should be properly quenched without any excess of water. Over-quenching spoils the surface, injures the structure and fractures the coke. When the coke is charged into the furnace by weight, a low moisture content is important also in confining the variations to a smaller range.

The physical standard by which blast furnace coke is generally measured, besides hardness and resistance to abrasion, is its porosity. It has been recognized that an open cell structure favors rapid combustion whereas a dense

structure retards it. Since the speed of combustion primarily affects the furnace practice, it appears that the combustibility of cokes should be considered a foremost quality.

The importance of the combustibility of cokes was first brought to my attention in 1906, through the use of bee-hive Pocahontas coke on the large furnaces at the South Works of the Illinois Steel Company. In appearance and structure it differed from the Connellsville and Klondike grades, but the porosity tests scarcely revealed the great difference in the action of these cokes in the furnace. A furnace which on Connellsville or Klondike coke worked normally, would on Pocahontas drive at an excessive speed. The blast pressure would drop several pounds, and the hearth would become cold, necessitating a decrease of the tuyere area and wind volume, and a lightening of the burden.

The extreme softness of the coke evidently made it highly vulnerable to dissolution by CO_2 in the furnace stack. This and excessive abrasion reduced it to small size, favoring "direct" reduction, which accelerates the movement of the stock, and not sufficient coke reached the tuyeres to maintain the temperature of the hearth. On the small furnaces at the Union and Milwaukee Works this coke, for apparent reasons, gave better results.

At this time I made a series of combustion tests with these cokes, which showed vast differences in the time required for the complete combustion of a fixed amount of coke with natural draft under equal conditions. The time required for complete combustion of the bee-hive Pocahontas coke amounted to only 47.7 per cent. of the time required to burn the same weight of Connellsville or Klondike.

With these results at hand we experimented in the following years with different mixtures of these cokes, in order to arrive at the degree of combustibility which would produce the best results in conjunction with our ore mixtures and furnace lines. In this manner bee-hive Pocahontas coke was successfully used in mixture with hard cokes. The best proportions proved to be two-third hard and one-third soft coke, as illustrated by the performance of No. 6 blast

furnace at the South Works, which from January 3rd, 1909, to December 18th, 1910, on this mixture, produced 307,517 tons of basic iron, with an average fuel consumption of 1,969 pounds of coke per ton of iron.

The early coke produced in our by-product ovens, even from the same coals, burned too slowly and made our furnace operations exceedingly difficult by preventing rapid and continuous movement of the stock. Observing the action through the tuyere glasses would reveal each piece of such coke moving slowly and requiring considerable time before being entirely consumed, whereas coke of proper combustibility dances lively at the tuyeres and quickly disappears. With fast-burning coke, each molecule of oxygen in the air immediately finds its molecule of carbon in the tuyere zone, and the combustion takes place rapidly and with great intensity. By thus concentrating the combustion in a comparatively small area, the highest heat effect is obtained. With slow-burning coke, on the other hand, the molecules of oxygen are not all able to combine immediately with their molecules of carbon. The result is that the combustion is carried higher up in the furnace, the heat generated by combustion is spread over a larger area, and the top temperature increases. The coke pieces being consumed but slowly, no rapid shrinkage of the stock takes place, such as characterizes a fast driving furnace with a highly heated combustion zone. Consequently the blast pressure goes up, the furnace begins to hang, and good practice becomes impossible.

On small furnaces such slow burning coke interferes even more seriously with the practice than on large furnaces, because the wind volume and pressure cannot be sufficiently increased to accelerate the combustion. The extremely poor results with some by-product coke led to the breaking of the larger coke pieces, with the object of increasing the active surface of the coke charge and improving the combustion particularly for the use on smaller stacks. While better results were obtained in this manner, the proper remedy is the manufacture of a coke with suitable and uniform combustibility.

This is achieved not only by using the proper coal mix-

ture and coking time, but primarily by careful heat distribution in the oven, avoiding overcoking part of the coal charge, which destroys the combustibility, and undercoking of other parts, which makes a product too soft and solvent in CO_2. The coking must be finished simultaneously at all parts of the cake of coal, which at that moment must be pushed and quenched without delay.

The following laboratory tests illustrate that by-product coke can be made of even greater combustibility than standard Connellsville bee-hive coke:

Kind of Coke	Comparative Loss of Various Cokes on Ignition in a Limited Current of Air — Loss in Weight at							
	300°C.	400°C.	500°C.	600°C.	700°C.	800°C.	900°C.	1060°C.
By-Product:								
No. 1	.20	.20	.79	13.55	15.35	14.90	15.95	19.80
No. 2	.64	.59	6.23	14.50	15.75	15.72	16.80	22.48
No. 3	.62	.47	4.18	14.55	15.70	15.60	16.20	22.60
Kentucky Bee-hive	.46	.78	3.90	13.40	15.80	14.35	15.40	20.75
Connellsville Bee-hive	.15	.15	.58	9.15	13.70	13.25	14.10	17.00

The lack of knowledge and experience along these lines was responsible for the slow progress attending the introduction of by-product ovens in this country. The product at first met with a good deal of opposition. Grades of coal similar to those which made a good coke in bee-hive ovens were used, and the coke obtained was too dense and gave very discouraging results, especially when used with Mesaba ores. Good blast furnace practice was not accomplished until such coals were substituted which, in bee-hive ovens, had made a coke too soft for blast furnace use. By modifying the oven operations in regard to heat regulation and coking time, the by-product coking process has made rapid strides in recent years, and to-day at a number of American plants by-product coke is made which rivals in quality our best bee-hive product.

As a practical proof of what has been accomplished in perfecting the quality and uniformity of by-product coke, the results obtained on the blast furnaces at the South Works with coke from the Gary and Joliet ovens, are of interest. The coke is made with a coking time of from 16 to 18 hours using 60 per cent. and over of low volatile Pocahontas coal in a mixture with various high volatile coals. The South Works furnaces, by their average coke consumption of 1,944 lbs. during the past twelve months, have established a yearly fuel record for any group of furnaces using a similar grade of ores. Monthly figures from May 1st, 1913, to May 1st, 1914, by stacks, were as shown in the table on page 31.

Limestone.

As the economical smelting of the finer and leaner ores of modern times requires special care in the manufacture of coke in order to obtain the best furnace practice, so also should we carefully prepare the flux and adapt it to the fineness of the ores and their increasing silica content.

The ore charges themselves have become so dense that any further additions of fines with the limestone are detrimental, and these should be eliminated by screening. At the same time, big lumps of stone are also more objectionable than formerly, because with the fast driving of a modern furnace they have not time to become properly preheated and reduced before they reach the melting zone. Lumps of raw lime usually make their appearance at the tuyeres when large stone has been charged. Stone for blast furnace use should, therefore, be crushed. Some stones are harder to reduce than others and should be broken relatively smaller. The fines should be eliminated by thorough screening.

Formerly, when the silica in the ores was so low that the cinder volume without the addition of special silicious materials was below the practical limit, a limestone containing 5 per cent. or 6 per cent. of silica was not objectionable. More silica in the limestone simply meant that less of these cheap materials could be used; but, providing it was uniform, it did not seriously affect the furnace practice. To-

ILLINOIS STEEL COMPANY, SOUTH WORKS

Average Daily Production and Coke Consumption per Ton
May, 1913, to April, 1914, inclusive

Month	Bessemer Pig Iron											
	No. 2 Furnace		No. 3 Furnace		No. 4 Furnace		"E" Furnace		No. 9 Furnace		Total Bessemer	
	Tons	Lbs. Coke	Tons	Lbs. Coke	Tons	Lbs. Coke	Tons	Lbs. Coke	Tons	Lbs. Coke	Tons	Lbs. Coke
May, 1913	543	1942	491	2179			565	1941	511	1963	528	2001
June	528	1974	411	2209	Blown out		570	1916	502	1958	503	2002
July	541	1912	408	2365	4–15–13		455	2087	468	1926	467	2057
August	515	1886	496	2006	Tonnage:		521	1912	469	1991	500	1947
September	508	1898	523	1890	723, 237		525	1691	516	1837	518	1828
October	496	1936	514	1964			514	1711	530	1849	514	1865
November	473	1946	528	1937	Blown in		467	1783	437	2144	477	1949
December			502	1932	2–15–14		536	1705	513	1798	515	1822
January, 1914	Blown out		474	1958			463†	1821			469	1903
February	11–23–13		479	2044	290	2464	489	1950	Blown out		445	2058
March			487	2061	518	1744	559	1815	12–18–13		521	1868
April	...	....	507	1991	543	1702	540	1845	...	....	528	1842
Average	517	1927	484	2023	485	1806	518	1851	492	1936	501	1927
Tons made on Lining	475,442		788,512		36,414		417,117		593,007			

Month	Basic Pig Iron											
	No. 5 Furnace		No. 6 Furnace		No. 7 Furnace (Basic)		No. 8 Furnace		No. 10 Furnace		Total Basic	
May, 1913	487	2159	422	1960	570	1828	467	2039	484	1926	486	1977
June	491	2195	413	1991	516	2077	439	2052	505	1893	473	2043
July	437	2177	396	2010	419	2103	506	1900	491	1923	450	2016
August	397	2351	433	1958	546	1987	482	1872	478	1962	477	1876
September			468	1873	530	1963	529	1792	500	1942	503	1893
October	Blown out		451	2007	531	1910	519	1840			500	1915
November	8–25–13		389	2016	572	1903	527	1894	Blown out		496	1929
December	Blown in		522	1654	582	1877	532	1886	10–1–13		551	1871
January, 1914	2–6–14				419‡	1986	536	1938			482	1958
February	402	2110	Blown out		529	2022	506	2029			484	2046
March	529	1882	12–4–13		532	2042	534	1888			532	1937
April	520	1910	...	....	567	1870	537	1904	...	....	542	1894
Average	476	2079	426	1969	526	1960	510	1915	492	1929	493	1961
Tons made on Lining	41,252		247,572		279,639		223,175		205,698			

Note.—No. 1 Furnace on special grades.
† "E" Furnace banked, Dec. 24, 1913, to Jan. 10, 1914.
‡ No. 7 Furnace banked, Dec. 24, 1913, to Jan. 10, 1914.

day, however, the natural silica in the ores has generally increased the slag volume to a point where it exceeds that required for carrying off the sulphur and insuring regular furnace operation. A reduction in the silica of the limestone represents, therefore, a direct saving in coke. It will also be found that the lower the silica content of a stone, the

more uniform it will be, which, of course, is a factor of the great importance.

While a moderate magnesia content in the slag is not objectionable, the use of dolomite is injurious to good furnace practice with Lake ores, where the slags are fairly high in alumina and where a low zone of fusion must be maintained. To eliminate the sulphur it has been found necessary in our practice to run on a more basic slag when using dolomite, which makes uniform furnace operations more difficult and results in a higher fuel consumption. With slags very low or very high in alumina, the use of dolomite has been found beneficial, as also in the manufacture of spiegel and ferro-manganese.

AIR.

Of all the elements introduced into the blast furnace in a given unit of time, air is the largest both by volume and by weight. It is therefore not surprising that great efforts were made towards its improvement. The cold blast of the early days was replaced in the beginning of the last century by the hot blast. With the iron pipe stoves first used, only moderate heats could be carried. Some fifty years ago firebrick stoves took their place, which allowed the blast temperatures to be increased to those of the present day. The introduction of hot blast marks the greatest step ever taken in improving the economy of the blast furnace. By the use of hot blast, combustion is accelerated, intensified and confined to a smaller space, the melting zone is concentrated, and the hearth assumes a higher temperature. The grade of iron becoming richer, demands more burden of ore to the charge of coke. This decreases the amount of gas per ton of iron and in turn reduces the top temperature, again saving heat and making possible a more economical reduction. It also causes less carbon to be consumed by CO_2 in the upper part of the furnace, whereby more is made available for combustion at the tuyeres. These effects being cumulative, the application of hot blast resulted in a far greater fuel saving than was expected from the mere addi-

tion of the heat units contained in the blast; and hand in hand with it went a large increase in production.

Another more recent method of obtaining fuel economy is the Gayley Dry Blast. The effect of this is the same as that of an equivalent increase in blast temperature. In addition it gives to the furnace a uniform supply of oxygen by weight. To this uniformity is attributed the extraordinary saving, particularly in localities with moist and variable climates, which in some cases was found to be greater than that corresponding to an equivalent increase in blast temperature.

Its applicability depends on local conditions, influencing the comparative cost of drying the air as compared with raising its temperature, and on the degree of existing furnace efficiency. At plants where a further increase of blast temperatures is not profitable because the limit of heat concentration is already reached, the dry blast will also fail to be economical except in the effect of its uniformity, which in natural air practice can only be approached by the most careful regulation of blast heats and of the weight of air blown.

The latest effort to improve the air, by the enrichment with oxygen, is being made in Europe, whether with profit or not remains to be seen. Since the ratio of CO_2 to CO cannot be increased above the point where the gas loses its reducing power, and this point remains the same whether or not it is diluted with nitrogen, and since this limit, as well as that of lowest top temperature, can be approached by the employment of less expensive means, it is at least doubtful if the oxygen method will ever come into general commercial use. The uniform heating of the furnace charges to the melting point requires time and a certain volume of gases, and these apparently cannot be decreased, even if it should be possible to shorten the reduction period by lowering the inert nitrogen content of the gas.

The hot blast and dry air blast bring an increment of heat into the furnace, while higher oxygenated air only intensifies the generation of heat from the fuel within the hearth.

CONSTRUCTION.

The manufacturer who, in the swift march of progress and in the pursuit of an industry, the foundation of which is ever changing with altering raw materials, does not constantly take stock of his equipment and rejuvenate it to suit the times, will soon find himself outclassed by his competitors.

With the variety of possibilities which present themselves in the operation of furnace plants, many forms of construction can be worked out and many can be made successful. But every improvement should be inspired by one common aim, and that is to facilitate the utmost uniformity of practice in order to gain the highest quality of product and the greatest possible economy.

Stocking and Charging Apparatus.

For the sake of uniformity and to eliminate the danger of mixing various grades and the necessity of frequent burden changes, adequate space and equipment for the stocking of ores should be provided. This feature will allow of a greater latitude in selecting the most suitable furnace burden at a given time. If a cargo can be spread evenly over a large pile, so that any cross section of it represents a true average of all cargoes received during a shipping season, the furnace will receive the ores in the most uniform shape.

The bins should be so designed that the ore can be easily withdrawn under perfect control on the part of the operator. With sufficient slope and closely spaced gates to prevent the sticking of the ores in the corners, proper movement of the entire contents can be secured. Furnace troubles are always more frequent in winter than in summer, due to the difficulty of correct charging when the materials are frozen. In cold climates, therefore, the charging floor should be enclosed and the bins heated, preferably by waste gases.

In handling the coke, the main object should be to avoid abrasion. That charging system is preferable which transfers the coke from the ovens or railroad cars into the furnace

with the least number of drops. The coke can be charged by volume or by weight. The former method is independent of varying moistures in the coke, and automatically compensates for certain variations in quality, by delivering a greater weight of smaller, denser coke. This regulation, however, is not always correct, since smaller coke is not proportionately inferior, but it tends to equalize the error. Where the coke is uniform in moisture and furnace value, the weighing method will give excellent results.

The coke pockets should be made of ample capacity to avoid delays, and should be designed to keep all of the contents in motion and to avoid the accumulation of fines—a most frequent cause of furnace troubles. The dust should be eliminated by screens placed in the bin or at the gates.

The charging or larry car should preferably be large enough to hold a full charge of ore and stone. This saves labor and wear by decreasing the number of trips, and allows the furnace to be kept full with the least effort, even when driving fast, at the same time rendering the percentage of error in weighing smaller.

The skip hoist can be either of the single or the double type. The latter has the advantage of filling the furnace faster, but brings with it the difficulty of obtaining an even distribution between the right and left side of the furnace, which must be overcome by proper construction of the top. Materials dumped from an overturning skip bucket will arrange themselves more or less according to size, the coarse particles falling the furthest and the fines remaining behind. In order to avoid uneven distribution of fine and coarse materials, the design of the skip bucket, receiving hopper and top should be carefully worked out; as should also the range of skip travel and the speed of dumping, which should be under positively fixed control. The single skip allows the use of a cylindrical bucket with bottom discharge, dumping centrally over the bell and giving a correct distribution on the top of the furnace. But with that design it is necessary to correct the distribution in the bucket itself with regard to coarse and fine materials. This is a difficult matter and can only be accomplished by rotating the buckets.

This type of hoist, however, has the decided advantage of more carefully handling the coke charges, and for that reason has been largely adopted in Europe.

Top Construction and Stock Distribution.

The blast furnace top itself has been the subject of more variations in design than any part of the furnace. Besides being a gas seal, it has to fulfill the important function of proper stock distribution. It is difficult to accomplish this with a stationary top, and many furnace men prefer to abandon it in favor of rotating mechanical tops. Whatever type of top is selected, it must be borne in mind that a break-down generally necessitates stopping the furnace; therefore the construction should be simple and strong. If a good distribution can be obtained without resorting to the complication of rotary mechanism, all the better. If deemed necessary to employ a rotating top, such a design should be selected which will give a satisfactory distribution, even if it should cease to rotate.

Many of the irregularities of stock distribution bear no relation to the design of the top; as for instance, the building up of ore on the big bell, which with Lake ores cannot be altogether prevented, even with the modern steep angles, and requires constant watchfulness, or the shifting of the furnace top relative to the furnace center caused by expansion and contraction; or the warping of the bell and hopper and the uneven wear of the stock-line. Neither can irregularities of charging—such as are caused by lack of care on the part of operator, severe weather, and many other causes—be corrected by any design of top. It will be seen, therefore, that a rotating top is by no means the cure of all evils. Careful supervision, constant vigilance, a regular and frequent inspection, are the only safeguards and should be practiced regardless of the type of top in use.

With a uniform distribution on the big bell, the next question is how the charges should best be arranged in the stock column. There are two opposite methods of depositing the materials in the furnace. The one, which is used abroad, but not in this country, consists in raising a

cylindrical bell and allowing the charge to glide off the hopper towards the center of the furnace, there forming a cone with an apex of fines and a base of coarse materials, which gives the gases a tendency to ascend next to the walls. This is counteracted by using a comparatively small hearth with tuyeres projecting far in, or a central gas off-take, and frequently by special stock deflectors. In European practice the stock column is much more open, less fines and considerable lump ores still being used with large sized coke and stone. Under these conditions this charging method seems to give satisfaction; and in many places it is still adhered to, in spite of the great complication of design, especially when combining the central gas off-take with a mechanical top.

Under our conditions, using practically none but fine ores, in order to obtain uniform practice, the principal aim must be to prevent the channeling of gases. As it is their natural tendency to follow the walls where the stock is continually loosened by friction, we deposit the ores next to the wall, thus forcing the gases to the center. In order to accomplish this we use a method opposite to the one described, lowering a large conical bell and dumping the charges against the furnace wall, the finer materials remaining there on a higher ridge, the coarser ones rebounding and rolling toward the center. This opens up the stock column in the center and serves the same purpose as a central gas off-take, only in a milder form. A recent experiment made at South Works with a central tube, showed conclusively that this arrangement is too radical for Mesaba ores.

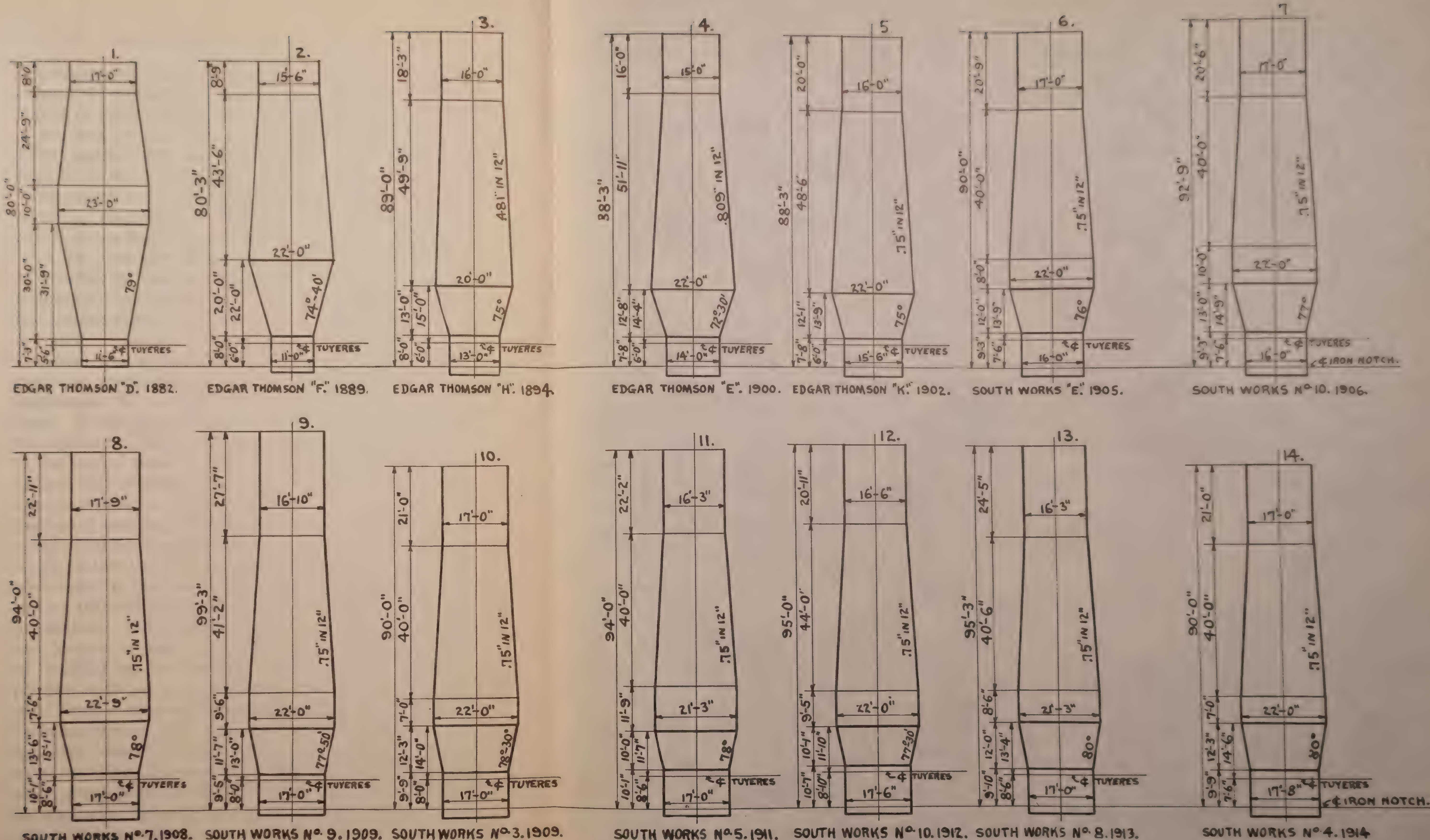
For the opposite purpose, that of loosening the stock next to the wall, various modifications of the plain bell have been tried. Such attempts originated in the early days of Mesaba practice, when it was thought that the formation of scaffolds could be avoided by placing less fines next to the wall. Designs of this kind have mostly been abandoned, as it was soon found that the evil of gases channeling along the walls and unreduced ores descending in the center, with high fuel consumption and buckshot iron as the result, was too high a price to pay for keeping the walls clean.

The plain bell with the gas off-takes at the periphery of the stack is evidently the best and by far the simplest design under our present conditions of raw materials. The problem to obtain a free working furnace on Mesaba ores could, however, not be solved until the correct furnace lines were established.

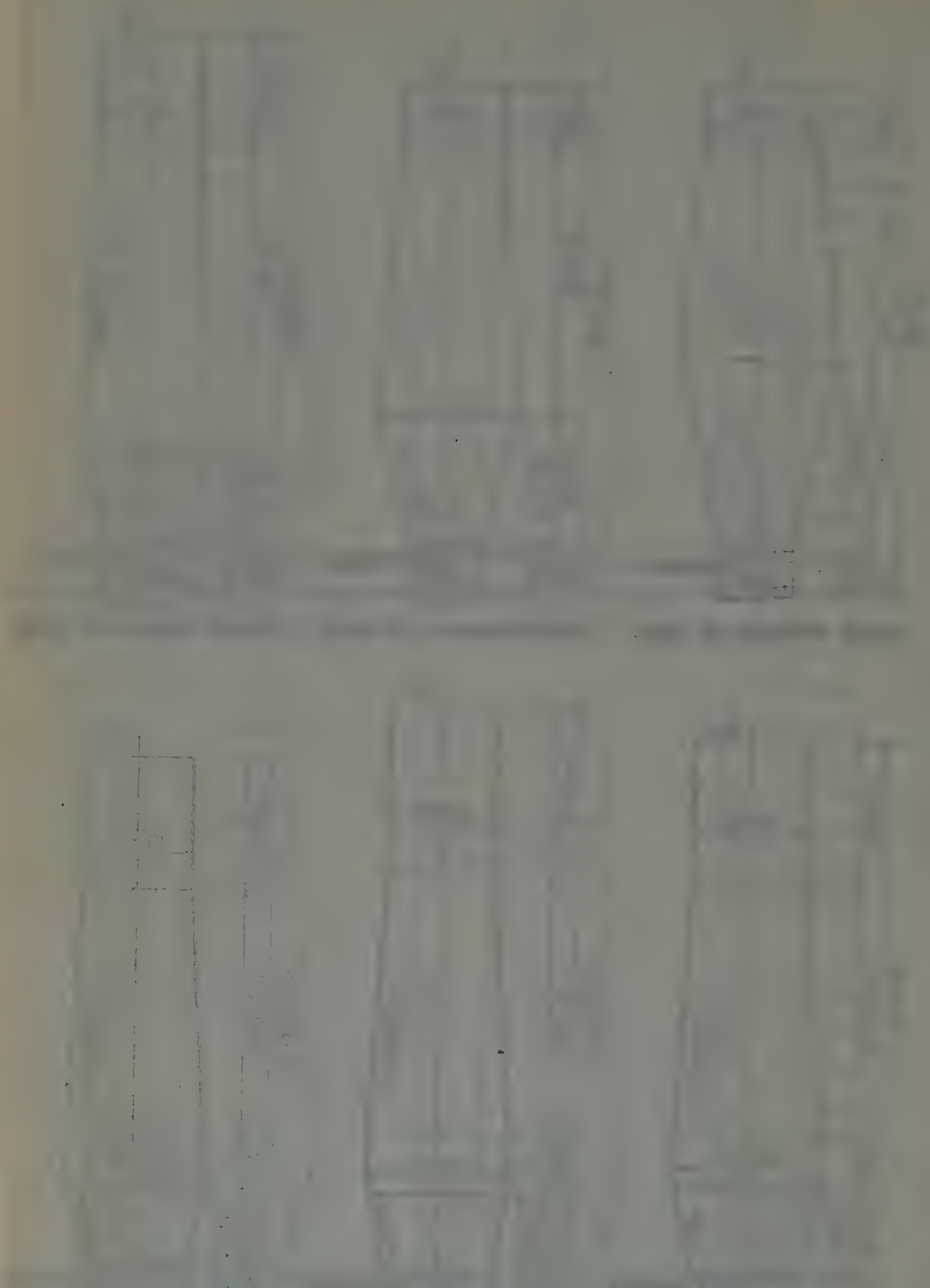
Development of Furnace Lines.

Going back in history, when Mr. James Gayley, in 1890, read before the British Iron and Steel Institute his memorable paper on the development of American blast furnaces, he outlined the trend of improvements in his concluding remarks by stating that in the last decade there had been three steps: First, in 1880, the introduction of rapid driving, with large outputs and high fuel consumption; second, in 1885, the production of an equally large amount of iron with a low fuel consumption, by slow driving; and third, in 1890, the production of nearly double that quantity of iron, on a low fuel consumption, through rapid driving. Mr. Gayley himself, who was then in charge of the Edgar Thomson furnaces, was largely responsible for this progress. Much credit also belongs to the management of the Illinois Steel Company, who on their Union and South Chicago furnaces made the best yearly fuel records of that period.

In the early eighties the linings at the Edgar Thomson furnaces had boshes half way up the stack; as, for instance, furnace "D," shown in Fig. 1 in the attached chart of furnace lines. This construction was taken over from the charcoal and anthracite practice with hard ores. It was realized that with coke as a fuel and with softer ores, much more rapid driving was not only possible but highly desirable, if it could be done without an increase in fuel. The furnace lines were conformed to this idea and the boshes lowered from 30′ to 20′, in the period covered by Mr. Gayley's paper. A furnace of this type is illustrated in Fig. 2, showing furnace "F" at Edgar Thomson in 1889. By the rapid yet consistent development of furnace lines and practice in this direction, and by strengthening his blowing equipment



FIGS. 1-14.—Showing the Development of Blast Furnace Lines from 1882 to the Present Time, as illustrated by the Furnaces built at the Edgar Thomson Works, Carnegie Steel Company and the South Works, Illinois Steel Company.



accordingly, Mr. Gayley was himself able in a few years to surpass the predictions made in his paper. By 1894 the output of these furnaces had been increased to an average of 400 tons per day with a coke consumption of less than 1,900 pounds. This was accomplished by raising the stack from 80′ to 90′, lowering the bosh to 15′, increasing the size of the hearth to 13′, thus maintaining the previously established 75° bosh angle. A furnace of that type is shown in Fig. 3, giving Edgar Thomson furnace "H" in 1894.

A few years later Mesaba ores entered into the problem. In lowering the bosh and raising the furnace to 90 feet, still maintaining the 16-foot stock-line, the angle of the inwall had become steeper (see Fig. 3), and this had the tendency to retard the descent of the charges. The next step taken, therefore, was to increase the batter in the stack, which could be accomplished by narrowing the stock-line and lengthening the straight top section, or by widening the bosh. At the same time the advantage of still lower boshes was realized. These two developments together resulted in the type of furnace shown in Fig. 4, giving the lines of furnace "E" at Edgar Thomson in 1900. Furnaces of this type were able to produce 500 tons of iron per day on a burden of one-third Mesaba ores, but it was difficult to maintain uniform practice owing to accumulation of stock on the flatter bosh. This suggested the return to the 75° bosh angle by the use of still larger hearths, a step which was not taken without hesitation, as we feared an insufficient penetration. But no difficulty of that kind was experienced, and furnaces of this type marked quite an improvement, by establishing the average yearly putput of 500 tons per day on 50 per cent. of Mesaba ores with uniform practice. Such a furnace is illustrated in Fig. 5, giving Edgar Thomson furnace "K," built in 1902, which in 1903 averaged 539 tons of iron on 1985 pounds of coke. I have given the Edgar Thomson furnaces as an example, as they were representative of this development and, together with the Duquesne furnaces, established the best blast furnace records of that period.

Similar lines, consisting of a 16-foot stock-line, ¾ inch

to the foot batter of the inwall, a 22-foot bosh, 14′ 6″ to 15′ 6″ hearth diameter and a 75° bosh angle, were quite generally adopted on 90 and 100-foot furnaces using Mesaba ores. The percentage of these ores in the burden was gradually increased up to 70 per cent. in the next five years, but not without a distinct increase in coke consumption, as shown by the following figures representing the averages of a large number of American furnace plants using Lake ores:

Year	Per Cent. Mesaba	Lbs. Coke
1902.......	43.8	2,155
1903.......	50.3	2,191
1904.......	55.0	2,239
1905.......	61.0	2,275
1906.......	65.2	2,343
1907.......	68.7	2,362

The first experience with these ores had clearly shown that on account of their reducibility, they could be smelted rapidly and with a low fuel consumption, providing the furnace could be made to work uniformly, and the walls could be kept clean. The more regular, faster movement of the stock—by offering less opportunity for the gases to channel, and a more intimate contact and better heat exchange between ores and gases—allows a heavy burden to be carried in spite of the faster driving. The zone where the materials become plastic is kept at a uniformly low level, and there is less danger of scaffolds forming above the bosh. The task, therefore, is to design a furnace in such a way that the least resistance is offered to the free travel of the stock. With the proper batter already established, the chief impediment remains the bosh. As the melting zone is lowered, the bosh must follow, otherwise the materials will strike the inverted angle before the proper shrinkage through fusion takes place, causing the furnace to hang. Furthermore, a steeper angle should facilitate the stock movement in the bosh, and should, in conjunction with an increased hearth diameter, tend to keep the materials loose in arriving at the tuyere zone, allowing a free penetration

by the blast and preventing high blast pressures. The bosh seemingly has but one important duty—that of retarding the melting ores, so they will not run ahead of the coke and darken the tuyeres by reaching them before being properly prepared. These ideas were embodied in successive linings of the furnaces at South Works by increasing the hearth diameter up to 17′ 8″, decreasing the height of the bosh above the tuyeres below 12′, and steepening the bosh angle to 80°, a development which is clearly shown by Figs. 8–14 on the table of furnace lines.

In the latest models of these furnaces the bosh is no longer a conspicuous part and there is nothing to indicate that we have reached the limit in low and steep boshes, simply by further widening the hearths and without resorting to such means as the elliptical furnace. The hearth diameter, and not the bosh diameter, must to-day be recognized as the determining factor in influencing the rate of output. In designing new lines, the hearth dimensions should be established first, according to the desired production. By adding a bosh of correct height and angle, the bosh diameter automatically results.

As will be seen on the table of lines, stacks of different heights are in operation at the South Works. Whereas laboratory tests show that Mesaba ores can be completely reduced in a few hours by furnace gases at suitable temperatures, actual conditions are different. Practical experience proved that even with these easily reduced ores it takes considerable time, first, to thoroughly preheat every particle in a large bulk of ore, and then to bring it into contact with the volume of gases required to complete reduction. This led to a gradual increase in the height of stacks as the output was increased. Experience seems to show quite clearly that, for Mesaba ores, the proper height is 90′.

A greater height of the stack than that necessary to accomplish the desired reduction is not only useless, but detrimental by extending the zone where the coke is attacked by CO_2, and unnecessarily increasing the blast pressure. Furnaces which are too low compared to their hearth diameter have too low a blast pressure to give a proper penetration

in the combustion zone, if driven at the rate most suitable for economical reduction. If higher blast pressure and better penetration are obtained by increased wind volume, the zone of fusion rises and the time available for preheating and reducing the ore charges becomes too short, resulting in an excessive proportion of "direct" reduction by solid carbon. Furnaces operated in this manner are able to produce as large, or larger, tonnage than similar stacks of greater height, but will invariably show a higher fuel consumption. The practice of carrying the stock-line at a lower level has the same effect—the tonnage is increased at the expense of fuel consumption, except where the furnaces are too high, in which event they should be cut down rather than jeopardize uniform distribution and life of lining.

The diameter of the stock-line should be carefully chosen to correspond with the hearth and the prospective volume of wind. It should not be appreciably smaller than the hearth, otherwise the dust loss when using fine ores will be excessive. Neither should it be materially larger, as it would be difficult to attain the desired batter of the inwall without extending the cylindrical top section too far down, or inserting too high a cylindrical section above the bosh, both of which are liable to interfere with the smooth travel of the stock. The stock-line approximately determines the size of the bell. With Mesaba ores a bell of from 3′ to 5′ smaller diameter than the stock-line has given the best results. The method of charging has some influence on this relation.

The number of tuyeres, if kept within certain limits in proportion to the size of the hearth, is of little importance, since not their number but their combined free area determines the degree of penetration with a given wind volume. At the South Works ten and twelve tuyeres are used with equally good results on the largest hearths.

The relative position of the tuyere level, cinder notch and tapping hole deserve the most careful study. By increasing the height of the tuyeres above the cinder notch, a larger amount of slag can be held and the clogging of the tuyere zone with slag, which interferes with the combustion, is prevented. The greater the distance between cinder and

iron notch levels, the smaller the danger of the iron reaching the cinder notch and causing damage. With a fixed hearth diameter, this distance determines the maximum weight of individual casts. However, it cannot be increased except in proportion to enlarged output, otherwise the bath of iron, removed too far from the active tuyere level and held too long in the furnace, will cool and cause those manifold troubles due to physically cold iron, which affect furnace and steel works practice alike.

Since the character of the ores is changing all over the world, much in the same direction as in this country, the development of furnace lines in other countries will in all probability be similar.

Preservation of Furnace Lines.

Having established suitable lines, the next problem is to maintain them. Nothing contributes so much to the long life of a lining as a low fuel consumption and uniform practice. The hearth and bosh, which in the early days usually determined the length of a campaign by giving way first, are on our modern furnaces so efficiently cooled and so strongly armored that they outlast the lining in the stack. The ability to maintain the bosh indefinitely, by the insertion of cooling plates, led to many attempts to follow the same construction in the inwall. But the plates caused the lining to become corrugated between rows and to wear back above the top row, forming shelves highly inducive to scaffold formation. Furthermore, it was not an easy matter to so arrange the plates that they could be exchanged when leaking. Cooling plates above the mantle have only survived where they are placed from 18 to 22 inches back of the face of the inwall, and in this position they have not much effect in preserving the original lines. These difficulties led to the construction of thin lined furnaces on both sides of the water, from 9″ and 13″ of brick work in this country, and from 3″ to a mere coating of clay used on a few German furnaces. Very thin linings have only proved advantageous for making special grades of iron or when using coarser burdens.

In districts of high fuel consumption the adoption of thin

linings may have resulted in a coke saving by lowering the average stack temperature through cooling from the outside. Where heat concentration in the hearth and corresponding lower stack temperatures are reached by more efficient means, such intense cooling represents a direct loss. With Mesaba ores it is impossible to prevent the fine materials from building up on the cold shell, after the lining is worn away. Therefore the life of a thin lining is determined by the life of the brick work itself, and this is too short in the case of a 9″ or 13½″ lining to make this construction profitable.

Excessive thickness of a lining has no advantage, since before it wears out, the lines become so irregular that economical practice is impossible. From 22½″ to 36″ seems, therefore, the proper thickness. A good lining, if allowed to become properly seasoned and coated will wear slowly and uniformly, providing the stock and blast distribution is correct. A stack lined with a moderately thick lining does not require water cooling, but when the brick work does wear, the campaign can be prolonged by the application of water sprays without much deviation from the original lines.

The quality of the fire brick is the next important item in prolonging the life of a lining. The hearth and bosh brick are protected by efficient cooling; the top brick generally by wearing plates. The problem is to obtain brick for the lower inwall which will last without protection. Here they are exposed simultaneously to abrasion and high temperatures. They must, therefore, have a high melting point and yet be hard and tough. The quality of clays and their treatment, as well as the various methods of brick manufacture, enter here. Machine-pressed brick are especially well adapted to meet the requirements of a good inwall, and owing to their correct shapes can be laid with narrower joints. They have given excellent results at the South Works during the past five years, from six to eight hundred thousand tons of iron being obtained on a lining, and with good practice to the end. In Germany carbon brick are frequently used in the hearth and bosh, with varying results and opinions widely differing as to their value.

A great variety of wearing plates have been designed to protect the stock-line, but very few have proved successful. The plates should be made in small enough sections and of such metal and design that they will neither crack nor warp. To prevent their working loose and interfering with the distribution, they should be tied in with the brick work. Some furnace men prefer to avoid the complication of such arrangement by repairing the brick work at the stock-line during the campaign.

Stack Construction.

The strong, riveted, steel plate shell surrounding the brick work is one of the best features of our construction. It is now made so heavy that the lining can be laid quite close against it, insuring tight joints, which are forced to close with the expansion of brick work. The shell may serve the purpose of supporting the top ring, hopper and downcomer pipes; but the skip hoist and dumping mechanism should under no circumstances be attached to it. These must be supported independently to avoid shifting with the expansion of the furnace. The furnace shell protects the brick work and allows weak spots in the lining to be held for long periods by the application of water sprays In Germany furnace shells are found only exceptionally and on older furnaces. The construction commonly used there encircles the brick work with steel bands. Many stacks are cooled, sometimes up to the top, by open cast iron water boxes which are placed between the bands and generally extend to within a few inches of the interior face of the lining. For this construction is claimed the advantage of accessibility when repairs to the brick work are needed. In some instances German stacks have been practically relined without blowing out, by banking below the mantle. The furnace with a steel shell is certainly stronger and safer, and can be kept in blast under conditions which would force an open furnace out of operation. Our practice would seem to prohibit the German construction on account of high blast pressure, loss of gas, and danger of ruptures in case of heavy slips. In the bosh where we employ the

German stack construction, they often use a steel jacket, similar to the one employed in this country on Eastern furnaces using magnetites and imported ores. With Mesaba ores the more intense cooling of the water-sprayed jacket causes accumulations to form on the bosh, which periodically melt down, making the practice very irregular.

The gas off-takes should be located as high above the stock-line as possible, out of the path of the falling stock. There should be several, preferably four, and their area should be sufficient to prevent excessive velocity. In this manner, and by turning these off-takes upward before they lead down to the dust catcher, the amount of flue dust and fine coke carried over has been decidedly reduced. One or more good safety bleeder valves should be provided, so designed that they will give ample relief during heavier slips without allowing any coarse materials to be thrown out.

Gas Cleaning.

The dry gas cleaning system need only consist of one dust catcher of good size and an efficient centrifugal cleaner. These will eliminate practically as much dust as more elaborate arrangements, and are economical in construction and operation. A primary gas washing plant of sufficient capacity to wash all the gas for stoves and boilers should form part of every modern furnace plant. There is no question as to the value of washed gas for stoves, and a proper design of boiler settings, to allow of a free development of the flame and complete combustion before the gases strike the colder surfaces, will render it economical for boilers also.

Stoves.

With washed gas the problem of stove construction becomes comparatively easy. Small checkers can be employed and thereby the heating surface is increased sufficiently so that four large stoves will furnish all the heat required. With clean gas these can be kept in continuous service. They form a simpler layout and are preferable to five

smaller stoves on account of better heat economy, less radiation surface and fewer valves.

The latest innovations, which come to us from Germany, claim to increase the capacity and efficiency of existing stoves by using compressed air for combustion, or by installing heat interchangers in the chimney flue for preheating the air.

Blowing Engines.

When using fine ores, strong blowing equipment is essential to insure the delivery of a uniform amount of wind, even under conditions of high blast pressure. Gas engines of good design and liberal dimensions have proven to be especially adapted for this service, since the cost of blowing is but little affected by high blast pressures, whereas it can be made almost prohibitive in the case of steam engines in districts of high cost of fuel. The great economy of the gas-blowing engines has been a long established fact. Practice in recent years has proved their reliability in service, and has thereby definitely decided in their favor against reciprocating steam-blowing engines, except in a few localities favored by very low coal prices or at isolated furnace plants where the surplus gas is not utilized, and therefore has no value. With the gradually increasing cost of coal mining and the growing tendency to make economical use of the surplus gas, the gas engine will continue to enlarge its field of usefulness. The steam turbo blower may conquer a position in the localities least favorable to gas engines, owing to its low cost of installation, small space requirement and simple operation. However, practice has not yet definitely proved that it will deliver as constant a supply of air as the reciprocating engine, particularly when fine ores are used, and the resistance in the furnace is subject to considerable and sudden variations.

OPERATION.

Practical experience had developed the blast furnace to a remarkable degree of efficiency long before science attempted to shed any light on the process. In the old

days the blast furnace was regarded as much of a mystery, and only practical men, through spending most of their lives with it, were capable of successfully controlling its whims. Good furnace men of this caliber were naturally scarce, and being rather jealous of their knowledge they were reluctant to teach others what they had acquired through years of hard work.

It was not until the middle of the past century that men of science gave to the industry a clear understanding of the important reactions in the furnace. This at once led to the realization that the process could be scientifically controlled, and soon the chemical laboratory was universally called upon to assist in regulating furnace operation. Then started a gradual transformation of furnace practice and, to speak in medical terms, the former curative or surgical methods were replaced by preventive treatment. The composition of the charges being known, the analysis of the resulting product could now be determined in advance, and its quality controlled with far greater certainty.

With the better selection and preparation of raw materials, more suitable furnace construction, better blowing equipment and stoves, the furnace operation became more and more a science; the more accurate knowledge as to the causes and effects of the detrimental reactions enabled the furnace manager to more successfully counteract them. While it was the essential qualification of the old type of furnace man to be expert in getting a sick furnace out of trouble, a task at which he gained plenty of practice, nowadays scientific management is expected to keep the blast furnace out of trouble and through perfect control of raw materials and furnace practice establish a uniform, economical operation.

Blowing in.

Having established the correct lines the foundation of a successful furnace campaign is laid by the utmost care and caution in blowing in. After a thorough drying of the lining the fire should be lighted simultaneously and uniformly all around the hearth and be given the opportunity to penetrate quickly into the center of the furnace. Whether a

wooden scaffold is used for preheating the coke charges before they reach the bottom, or the hearth is filled with coke and a pipe is inserted through the tapping hole to carry part of the combustion downward, either method thoroughly heats the bottom and the first casts are of good grade and can be tapped without difficulty.

The proper stepping up in weight of burden and wind can only be established by experience. If in doubt, it is better to err on the slow side. In order to avoid channeling on the walls on the one hand, and building up on the bosh on the other, the tuyere area should be increased in proportion to the amount of wind blown.

To establish a low top temperature from the very first, the burden should be increased in advance of the wind. In this manner a new furnace can be made to carry the highest possible ratio of burden in the second week of operation. By gradually following with the wind volume and bringing higher blast heats into play, it is possible to maintain this heavy burden and reach a high production on a low fuel consumption with a comparatively small amount of wind blown. This practice saves the new lining and permits it to become thoroughly seasoned and hardened. The first slag should not be so acid as to scour the walls nor so basic as to accumulate on the bosh. It should be just "limey" enough to liberate graphite from the iron and form a thin protective coating on the brick work. To maintain a most nearly perfect slag, every preference in the selection of raw materials should be given to a new furnace. As the lining becomes older it becomes more seasoned and suffers less variations.

Furnace Practice.

After the furnace assumes its proper pace, which means such a rate of driving as can be maintained without decreasing the previously established maximum ratio of burden, there should be as few radical changes as possible. The most advantageous unit of burden charge must be established by experience for each type of furnace, as well as the best method of dumping, and these should be varied only if the necessity for a change is definitely proved.

Any variation in the temperature and analysis of slag and iron should be promptly recognized and counteracted, at first by applying the reserve heat, then, if proper diagnosis indicates the necessity, by decreasing the burden. It should be borne in mind that "a stitch in time saves nine," and a slight change in heat or a small decrease in burden, quickly applied, will generally prevent more serious trouble. Coke blanks should be avoided as much as possible, as strong remedies of that nature tend to make the furnace fluctuate and disturb the desirable working lines which previous economical practice has formed.

The average blast temperature carried on furnaces burdened with Mesaba ores seldom exceeds 1100° F., ranging far lower than the blast heats commonly applied in European practice, and also lower than on most of our Eastern furnaces using magnetic ores. This is due to the fact that with the easily reducible Mesaba ores very low fuel consumption can be attained with comparatively low blast heats, providing the distribution and the furnace lines are correct. In fact, it occurs that furnaces operating with high blast heats side by side with furnaces using low blast heats, will require more coke, simply because in the latter heating and reduction are carried on more economically. The frequent failure to obtain any saving with high blast temperatures, coupled with the other common experience of Mesaba furnaces refusing to "take" the high heats has at many plants resulted in delaying the improvement of stove equipment and gas washing, so that even where the value of higher heats is recognized they are now often not available.

The ability to use high blast temperatures is determined by three factors: First, the physical condition of the stock in the furnace; second, the chemical and thermal conditions in the hearth; and third, the CO_2 to CO ratio in the gas. The first condition is determined by the physical character of the raw materials, their distribution in the stack, and the furnace lines, all of which influence the permeability of the stock column. The second condition is influenced by the fusibility and fluidity, as well as volume and basicity of the

slag, which are generally determined by its duty of sulphur elimination. The third condition depends on the reducibility of the ores and the grade of iron to be produced.

Uniformity in every respect will greatly facilitate the use of high heats, even if one or the other of the premises mentioned should not be favorable. A sudden increase of blast heat raises the hearth temperature and renders the slag more "limey" by reducing more silicon into the iron. With a dense stock column this will frequently cause an increase in blast pressure and will retard the action at the tuyeres, a condition which is aggravated by coke of slow combustibility and too small a cinder volume. A low percentage of slag will not only exaggerate the variations in analysis but will prevent the free descent of the stock and the desired penetration of the hearth, particularly when the shrinkage of the materials in the bosh through fusion is less than that required by the bosh angle. With high or flat boshes a greater cinder volume is necessary to insure smooth working with high blast heats than with low steep boshes.

Eventually the movement of the charges may stop altogether, and the furnace hangs. By then lowering the blast temperature the fusion zone can be extended until it reaches the plastic, limey agglomerations suspended in the bosh; and with the reduction of hearth temperature the slag again becoming more acid and fluid, the materials begin to melt and the stock column resumes its regular movement.

The greater the number of different elements contained in a slag the greater is its fluidity. This depends on the ability of the various components to enter into solution with each other, and must not be confused with the fusibility of slags. The latter is mainly determined by the chemical composition, and varies greatly with the proportion of the different components and their tendency to form new combinations with each other. The same element which in certain percentages will render the slag more fusible will, if present in different proportions, render it highly infusible. It is one of the blast furnace operator's chief duties to so select his burden that the resultant slag will have the most suitable fluidity as well as fusibility. A transgression be-

yond the established range of desirable fluidity and fusibility, in either direction, is detrimental.

To permit high blast temperatures being carried and enable the furnace to work freely with a low melting zone, the slag must be kept uniformly acid. Once the melting process is carried too high up, the original bosh line is raised, the brick work above the bosh wears back, the bosh becomes too high, and any attempt to again lower the zone of fusion by the application of high heats and increased burden results in irregular operation by suspending the unmelted stock on the previously formed angle. This is why high heats cannot generally be used on a worn lining.

Under otherwise favorable conditions the use of high heats is often a matter of education on the part of the furnace crew. With the unavoidable variations in raw materials it is easier to operate on lower blast heats a lighter burden, and with richer gases, because of the greater margin of safety with plenty of heat held in reserve. The use of very high heats requires constant watchfulness, and any slight change in the furnace must be quickly perceived and counteracted.

The cost of heating the air increases with the degree of temperature, and simultaneously the rate of coke saving decreases; so that in practice the economical limit of high blast heats generally lies below the theoretical one, which is reached when the gases lack the necessary preheating and reducing power. In the case of Mesaba ores, which are easily and quickly reduced by the gases, fast driving is possible without running into "direct" reduction; and lean gases, low top temperatures, and a low fuel consumption are reached by the use of moderate blast heats, as illustrated by the following data of all the South Works furnaces of the Illinois Steel Company for a year:

AVERAGE PRACTICE, MAY 1, 1913, TO MAY 1, 1914.

POUNDS PER TON OF IRON.

	Avg. Daily Prod.	Ore Scale Cinder	Coke	Stone	Excess of Scrap Used Over Prod.	Flue Dust Prod.	% Mesaba Ore	Actual Yield
Bessemer...........	501	4,136	1,927	863	23	207	73.9	53.63
Basic...............	493	4,471	1,961	849	51	160	85.5	49.08

	Cu. Ft. of Air Per Min.	Blast Pres.	Temperature		Analysis of Iron			Analysis of Slag			
			Blast	Top	Sil.	Sul.	Mn.	SiO_2	Al_2O_3	CaO	MgO
Bessemer...	48,850	15.3	1,068	330	1.39	.034	.68	35.60	13.44	46.85	2.06
Basic.......	45,660	16.3	996	266	.97	.038	1.72	34.71	14.48	45.50	3.40

To indicate the extent of coke saving which is obtained, even in Mesaba practice by the application of higher heats than the average shown above, on furnaces with favorable lines, the following data giving the monthly practice of Bessemer furnaces using less than 1,750 lbs. of coke per ton of iron are of interest:

POUNDS PER TON OF IRON.

	Avg. Daily Prod.	Ore Scale Cinder	Coke	Stone	Excess of Scrap Used Over Prod.	Flue Dust Prod.	% Mesaba Ore	Actual Yield
"E" Fce.:								
Sept. – '13........	525	4,012	1,691	677	88	175	92.9	53.24
Oct. – '13.........	514	4,047	1,711	774	113	171	93.0	52.85
Dec. – '13.........	536	3,852	1,705	780	109	201	83.7	55.69
No. 4 Fce.:								
Mar. – '14........	518	4,062	1,744	781	17	193	67.4	54.76
Apr. – '14.........	543	4,003	1,702	752	73	227	66.5	54.40

	Cu. Ft. of Air Per Min.	Blast Pres.	Temperature		Analysis of iron			Analysis of Slag			
			Blast	Top	Sil.	Sul.	Mn.	SiO_2	Al_2O_3	CaO	MgO
"E" Fce.:											
Sept. – '13	47,750	15.1	1,225	317	1.30	.034	.61	37.25	11.21	47.58	2.16
Oct. – '13.	46,390	16.2	1,251	306	1.48	.043	.60	37.40	11.47	46.55	2.03
Dec. – '13.	45,510	15.7	1,250	300	1.33	.041	.71	36.12	11.48	48.46	1.97
No. 4 Fce.:											
Mar. – '14	41,140	15.7	1,170	274	1.29	.025	.59	33.48	15.67	45.39	3.85
Apr. – '13.	42,950	16.0	1,196	283	1.23	.027	.56	34.63	15.01	45.63	2.83

Where less reducible ore mixtures are used, part of the reduction must be accomplished by solid carbon, the top

gases are richer, and a much greater margin is left for fuel saving with high blast temperatures.

Uniform furnace practice demands that the blowing engines be so governed as to deliver a constant quantity of air and not to maintain a constant pressure. The smelting of fine ores requires still greater care and accuracy in this respect, and this has led to the effort to deliver a constant weight of oxygen to the furnace at all times. Where the Gayley Dry Blast is used, this is accomplished simply by maintaining a uniform speed of the blowing engines. Reciprocating engines running on natural air can be made to deliver a constant weight of oxygen by varying the revolutions according to atmospheric changes. To derive the benefit of lower temperature and moisture, the air should be drawn from the outside of the engine room. Turbo blowers can be governed by a regulating device in the air inlet, which is supposed to automatically deliver a constant volume of air. It does not correct for moisture and temperature variations, nor does it seem likely that such a fine regulation can ever be attained with a device which has to correct the much greater effect of varying resistance in the furnace.

With all of these adjustments there still remains the error of the varying volumetric efficiency of the blowing tubs, leaky valves, mains, stoves and connections. These are generally in excess of any assumption. Even when proper deductions for clearance and valve losses have been made, the actual air required to burn the carbon contained in the charges and available for combustion at the tuyeres is less than that calculated from the blowing engine revolutions. Engines equipped with modern automatic valves show better results in that respect; and turbo blowers, by obviating the pulsation, give the highest actual delivery. For better control it seems highly desirable to measure the air for each furnace. The practical possibility of installing flow meters in the cold blast main is now being demonstrated at South Works, where an instrument has recently been put in service and is giving very promising results. In Germany it is the practice at several plants to blow with all the gas

engines into a common main for all furnaces of a group. The engines are operated at the most economical speed. The blast pressure is held uniform and slightly above the maximum furnace pressure. The volume of air for each furnace is regulated by an automatic valve in connection with a flow meter. This system should give good results at plants where the blast pressure varies but slightly, and in connection with gas engines which, on account of their low gas consumption, can be operated against an increased blast pressure without materially affecting the blowing cost. With steam-blowing engines, where the fuel consumption constitutes the largest item of cost, and in practice where the blast pressures vary, this method cannot be considered.

A furnace will, at times, without any change in the wind or raw materials, start to drive faster, taking more charges. In this case the carbon introduced with the additional rounds of burden is consumed in the "direct" reduction with the ores or by solution in CO_2. In the combustion at the tuyeres the constant weight of oxygen blown can combine with only a certain constant amount of carbon to CO, generating a fixed quantity of heat. Therefore, the additional coke charged must be consumed by the oxygen in the ores or dissolved by CO_2. Under these conditions a furnace will run cold, unless sufficient blast temperature is applied to balance the heat lost by the "direct" reduction and solution in CO_2 as well as that required for the melting of the additional ore charges. If enough blast heat is not available, the wind must be diminished in order to re-establish the former equilibrium of "indirect" and "direct" reduction, and avoid the necessity of lightening the burden.

Practice on Various Grades.

Blast furnace operations are comparatively simple where the same grade of iron is made continuously. The practice becomes more intricate when frequent changes from one grade to another are required. Without good furnace lines it is impossible to vary the grades without loss of quality and economy.

In merchant furnaces generally much smaller hearth

dimensions are found than those which have been developed on modern furnaces connected with steel works, and higher or flatter boshes are frequently chosen, the former to accommodate the higher melting zone on foundry grades, and the latter to facilitate the production of basic iron, recognizing the value of low boshes but perhaps not the advantage of larger hearths. Such designs are poorly suited for successful operation on varying grades, particularly those which require basic slags. Merchant practice, above all others, demands lines which keep the furnace walls clean. The low, steep bosh accomplishes this, while the larger hearth favors uniformity of product and fuel economy. Foundry grades, spiegel, ferro-silicon, and ferro-manganese are being made in the large hearths of modern furnaces with excellent results, surpassing those obtained on smaller furnaces especially designed for such practice.

In producing these grades, the first step is to so modify the physical and chemical quality of the slag as to make it most favorable to the transfer of the desired elements into the iron, and to the elimination from the iron of those ingredients which are not wanted. For instance, in high silicon Bessemer or Foundry practice, a much lower fuel consumption can be obtained if, by a decreased proportion of bases in the slag its ability to retain silica has been lessened, thereby favoring the reduction of silicon into the iron. Lower fuel consumption and higher blast heats will then assist in concentrating the melting zone and maintaining a high hearth temperature, which will increase the ability of the leaner slag to dissolve and retain the sulphur, resulting in a uniform grade of low sulphur iron. The production of high grades of ferro silicon is made possible only by a large preponderance of silica in the burden and slag. Even then, the highest blast temperatures are required to reduce economically large quantities of silicon.

In spiegel and ferro manganese practice, where it is desired to reduce the maximum amount of manganese into the product, with the least loss of manganese in the slag, a very basic slag must be carried. By the utmost concentration of heat in the hearth through the use of the highest

blast temperatures, the slag can be kept sufficiently fluid, in spite of being very "limey," and the manganese in the slag can be held uniformly below 6 per cent. The loss of manganese in the gases, which occurs more or less in proportion to the top temperatures, is reduced to a minimum by concentrating the zone of fusion and thereby lowering the top temperature. By charging suitable percentages of raw coal, the distillation of which consumes heat, the top heats can be still further reduced. The temperature of the escaping gases can in this manner be kept below 600 degrees F., even when producing 80 per cent. ferro-manganese; and the gases, which are generally dark yellow or brown, can be observed issuing from stove and boiler stacks with but the faintest tint of yellow.

Below are some results recently obtained on No. 1 furnace at the South Works, which illustrate the practice just described:

	Total Tons	Daily Average	Coke per Ton	Coal per Ton	Temperature Degrees Fahrenheit		Average Grade	Per Cent Mn. in Slag
					Blast	Top		
Ferro-Manganese, Dec., 1913	3870	125	3896	288	1470	550	80% Mn.	5.81
Spiegel, Feb.–Mar., 1914	6528	272	2858	...	1167	607	19% Mn.	2.18
Ferro-Silicon, March–April, 1914	7396	161	3867	...	1214	676	11% Sil.°	....

On the same lining this furnace had previously produced 644,815 tons of Bessemer, basic, spiegel, ferro-silicon and ferro-manganese, which illustrates the possibility of making use of old linings for the manufacture of special grades.

Blowing Out.

A furnace campaign, however, should never be continued after the lining has become so warm that further economical practice is impossible. The expenditure for relining can be made comparatively small if the furnace is constructed with this point in view, and can generally be saved in a few months by the lower cost, resulting from better practice.

The unwarranted prolongation of furnace campaigns on worn-out lines is often a source of enormous losses in the manufacture of iron, and one which seems to be frequently overlooked in the effort to achieve a large production on a lining. It is poor policy to set a standard tonnage for a campaign, since one of 300,000 tons may be more destructive to the furnace walls than another of twice that tonnage. The economy of practice alone should determine the end of the furnace campaign. The vainglory of accumulating a large tonnage on a lining is a poor compensation for losing money, as well as the furnace organization's pride in a low fuel consumption.

The possibility of maintaining low fuel consumptions on furnace campaigns, and still reach high tonnages, is demonstrated by the following records as at May 1st of present campaigns of blast furnaces at the South Works of the Illinois Steel Company:

	Total Production	Average Coke Consumption
No. 1 Furnace—Operating on special grades.		
No. 2 Furnace.........	475,442 tons	2,044 lbs.
No. 3 Furnace.........	788,512 tons	2,056 lbs.
No. 4 Furnace.........	36,414 tons	1,806 lbs.
"E" Furnace.........	417,117 tons	1,939 lbs.
No. 5 Furnace.........	41,252 tons	1,944 lbs.
No. 6 Furnace.........	247,572 tons	2,116 lbs.
No. 7 Furnace.........	279,639 tons	1,975 lbs.
No. 8 Furnace.........	223,175 tons	1,923 lbs.
No. 9 Furnace.........	593,007 tons	2,028 lbs.
No. 10 Furnace........	205,698 tons	2,005 lbs.

Furnaces Nos. 2, 6, 9 and 10 were blown out last winter on account of business conditions and not on account of worn-out linings. The others are still operating.

In blowing out, the temperature of the escaping gases should be kept so low as not to cause any damage to the furnace top. This is accomplished by spraying water on the bell and the descending stock, and gradually decreasing the wind volume. Accumulations on the walls of stack and bosh should be cleaned off in the process of blowing out by using an acid slag and short tuyeres. A suitable quantity of fine materials, such as boiler ashes or granulated cinder,

charged on top of the final rounds of burden, will keep the blast pressure sufficiently high, even when the stock line approaches the tuyere level, to allow most of the iron and slag to be lifted out of the hearth during the last cast. This applies only to American practice where the tapping hole slants downward. In this manner a large amount of the labor for cleaning out the bottom can be saved. The danger of gas explosions is avoided by filling the gas flues with steam before any air is allowed to enter.

Furnace Gas, Its Output and Utilization.

By modern utilization of the by-products, their disposal, formerly a source of expense in the operation of a blast furnace plant, has been converted into a handsome profit. The furnace gas is the most conspicuous in this respect. It has become a potent, economical factor as the source of power for steel works and other industries or public utilities located in the district.

The rate of gas production and its total B.T.U. value is a function of the coke consumption, as well as of the pig iron output. Extensive tests were conducted at the South Works to establish the relation of these items and to determine the amount of surplus gas for the production of power which would be available from our furnaces under various conditions of practice. For two full years (1911 and 1912) on all blast furnaces of the plant making basic, Bessemer and spiegel, continuous gas samples were taken and analyzed every 24 hours, and the results were averaged for each month. The averages are plotted on Chart I. (page 60), each point representing a full month's operation of a furnace. On these averages and the monthly performance of the furnaces, the diagrams of Charts II. to V. are based. These show successively the relation of gas volume and heat value to coke consumption and that of pig iron output to coke consumption, volume and total calorific value of the top gases.

These diagrams show that the gas volume per ton of iron and the calorific value per cu. ft. of gas increase with higher coke rates, but that the fuel consumption, in our practice, decreases with an increase in output. It is this

latter relation which turns downward the curves on Chart IV., representing the amount and calorific value of the top gas per unit of time. These and the lines of Chart V., which

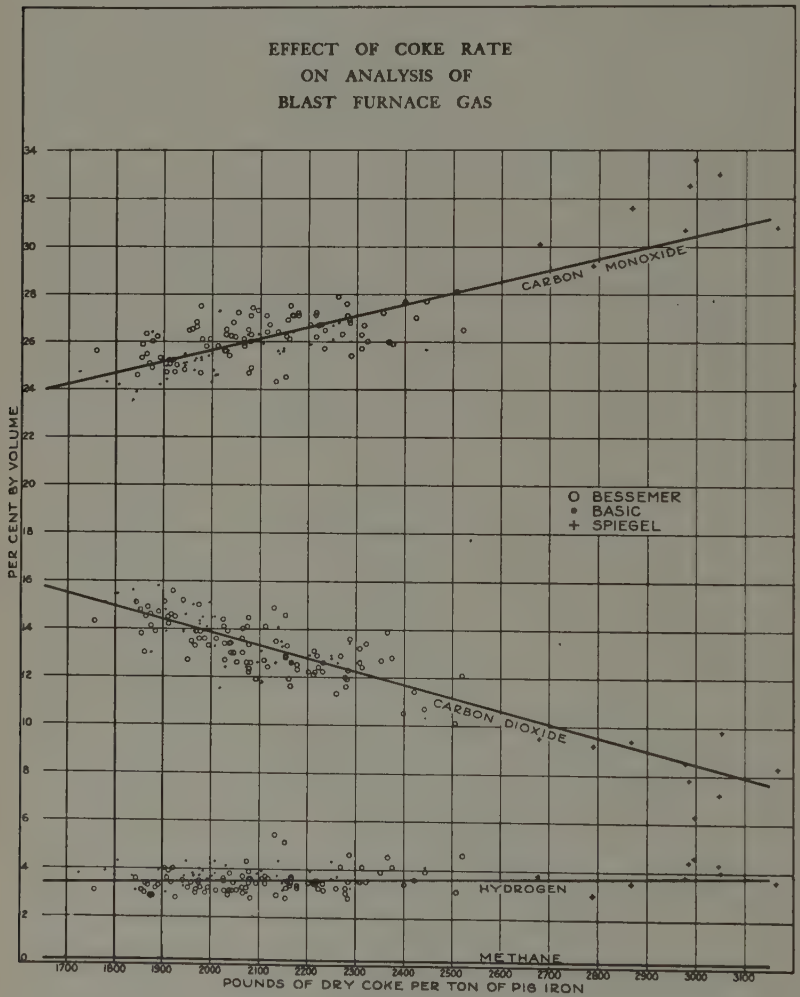


CHART I.

show the same items per unit of product, distinctly prove that with larger output, the amount of heat per ton of iron carried off with the top gases, decreases, and clearly demonstrates the economy of fast driving with Mesaba ores.

The heats of combustion of the constituent gases were taken as follows, sensible heat due to top temperatures not being considered:

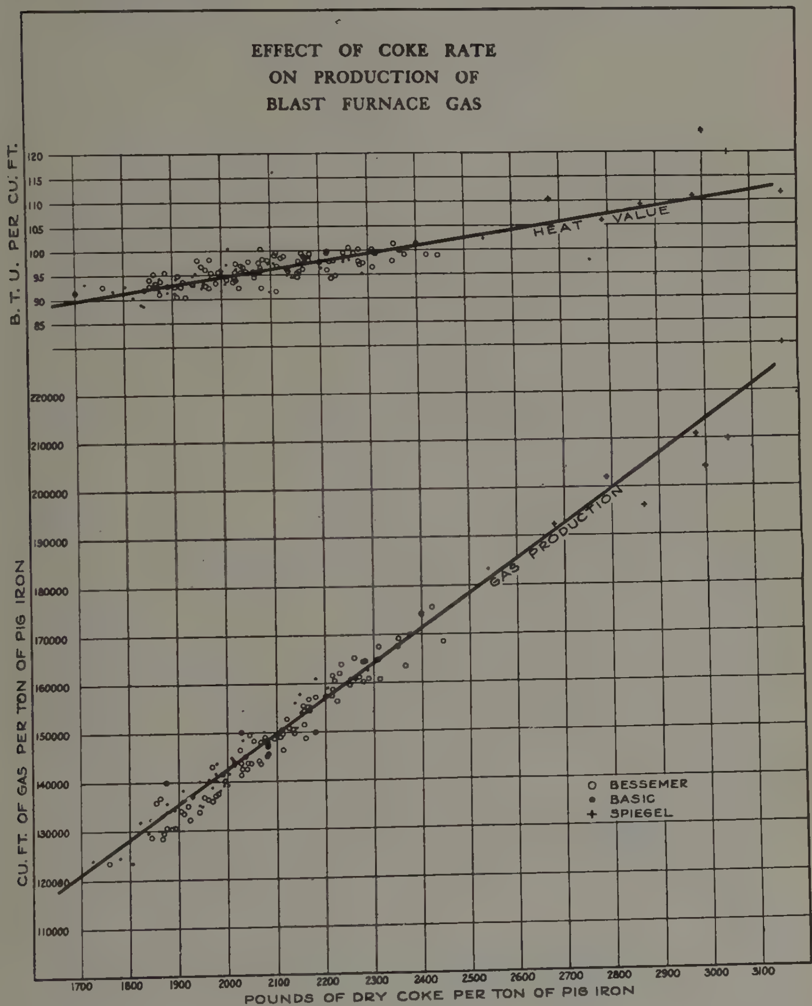


Chart II.

CO....................	324 B.t.u. per cu. ft.
H_2....................	275 B.t.u. per cu. ft.
CH_4....................	915 B.t.u. per cu. ft.

The computations of gas production, Chart II., are made on the basis that the carbon charged as coke reappears in

the gas, assuming that the weight of carbon in the limestone is equal to the carbon in the pig iron and flue dust produced. The error of this assumption is less than 1 per cent.

The method of calculating the volume of gas is as follows:

Tons Bessemer iron produced per day..	552.5
Coke rate, pounds per gross ton........	1,988
Carbon in coke..........................	88.72%
Analysis of gas:	
CO............................	25.8 %
CO_2............................	13.6 %
H_2............................	3.0 %
CH_4............................	.2 %
N............................	57.4 %
B.T.U. per cu. ft................	93.3

Cu. ft. gas per ton of iron,

$$\frac{1{,}988 \text{ lb. coke} \times 88.72\% \text{ C}}{(25.8\% \text{ CO} + 13.6\% \text{ CO}_2 + .2\% \text{ CH}_4) \times .0315} = 141{,}400$$

The constant 0.0315 is the weight of carbon in a cubic foot (at 29.92 in. and 62° F.) of any gas in which there is one atom of carbon per molecule. All volumes are referred to 62° F. and 29.92 in. barometer.

The following formulæ are based on these investigations, R being pounds of dry coke per ton of pig iron and T being tons of iron per 24 hours.

$$\text{B.T.U. per cu. ft.} = 0.016 \text{ R} + 62.5. \tag{1}$$
$$\text{Cu. ft. gas per ton iron} = 71.4 \text{ R}. \tag{2}$$
$$\text{B.T.U. in gas per ton iron} = 1.143 \text{ R}^2 + 4{,}462.5 \text{ R}. \tag{3}$$
$$\text{Cu. ft. air at tuyeres per ton iron} = 51.4 \text{ R}. \tag{4}$$
$$\text{Cu. ft. air per minute} = .0357 \text{ R T}. \tag{5}$$

Chart III. shows the relation of coke rate and tons iron per day during the performance of the same furnaces for the same period as shown on Charts I. and II. The mean line drawn through these points has the formula

$$\text{T} = 1{,}090 - .2875 \text{ R} \tag{6}$$

or,

$$\text{R} = \frac{1{,}090 - \text{T}}{.2875} \tag{7}$$

Combining (7) with (2) and dividing by 1,440 minutes gives

$$\text{Cu. ft. gas per min.} = 188.1\ T - .1{,}726\ T^2 \qquad (8)$$

which is plotted on Chart IV. Further, by combining (8) with (1) and (7) gives

$$\text{B.T.U. per min.} = 23{,}155\ T - 31.705\ T^2 + .00960\ T^3. \quad (9)$$

From (2) and (7)

$$\text{Cu. ft. gas per ton iron} = 270{,}710 - 248.35\ T.$$

While from (3) and (7)

$$\text{B.T.U. per ton iron} = 33{,}350{,}000 - 45{,}670\ T + 13.83\ T^2.$$

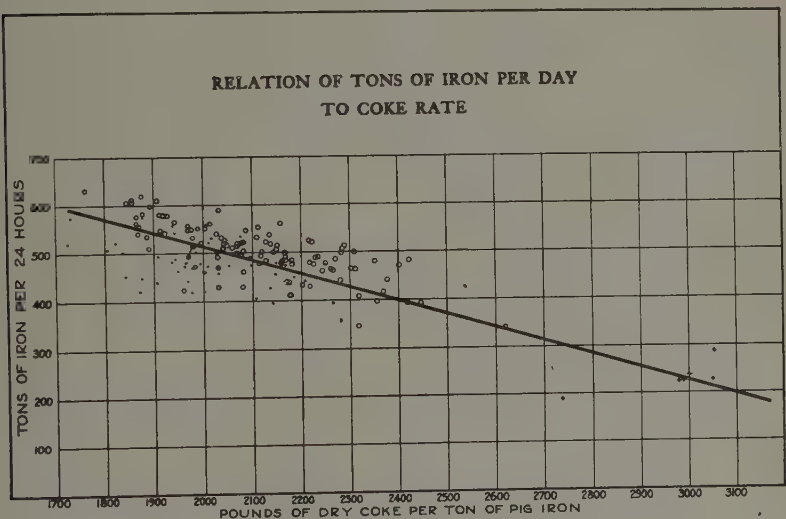


CHART III.

The curves on Chart IV. show that the amount of gas, and still more, its calorific value, is practically constant within the range of our usual daily variations of pig iron production. This feature is of special interest where other industries rely upon the blast furnace for a constant supply of power.

The nitrogen content of the gas, determined by difference, if plotted in conjunction with the CO_2 to CO lines on Chart I., forms an almost horizontal line. This indicates that

the air requirement per unit of carbon, in the practice represented by the test period, was almost constant. Even when the proportion of "direct" reduction was increased through fast driving, this evidently did not decrease the amount of carbon which reached the tuyeres appreciably more than

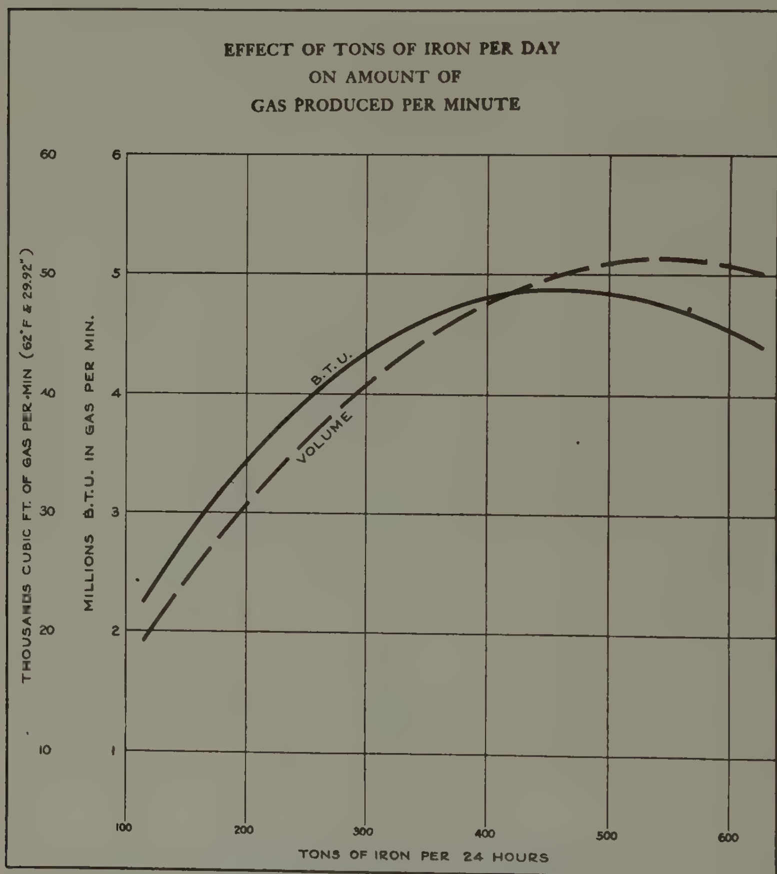


CHART IV.

the dissolution of carbon by CO_2 in the practice with higher fuel consumption, due to poorer coke or wornout lines. In the former case, the carbon, as well as the heat consumed by "direct" reduction, was replaced by an increase in blast temperature, smaller radiation losses, and other advantages

derived from fast driving. In the latter, the loss of carbon was replaced by an increase in coke consumption.

Recent experiments at South Works and Gary have proved that in times when there is no demand for the pig iron, the production of power can be maintained by con-

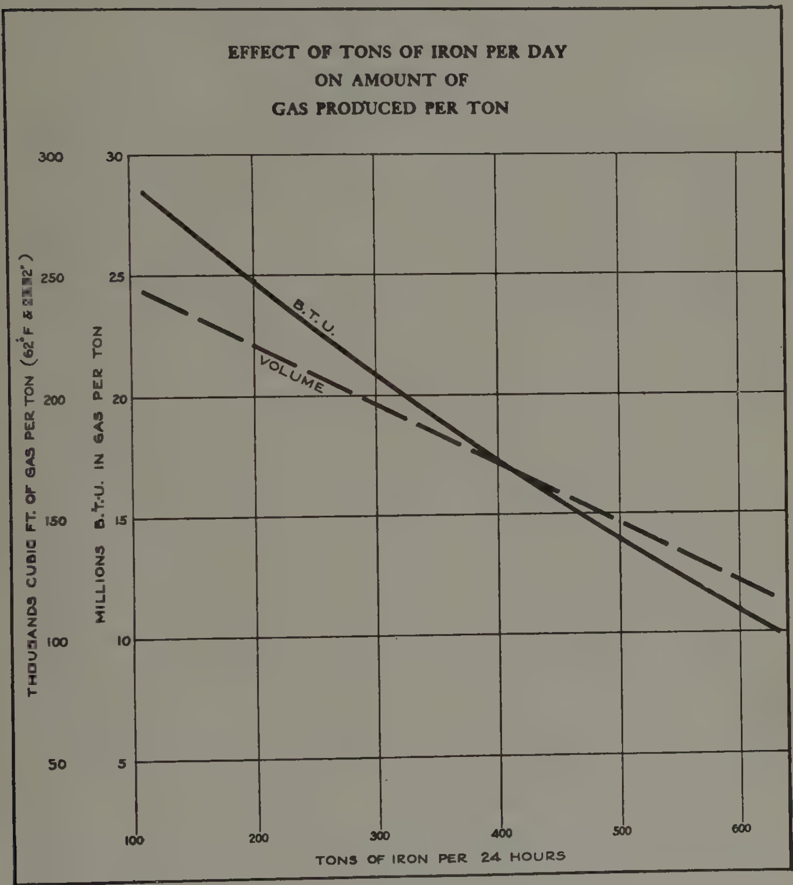


CHART V.

verting a furnace stack into a gas producer, charging a mixture of coke, coke breeze and coal with open hearth and other waste slags as flux.

The latest development in Germany is the mixing of blast furnace and coke oven gas. By automatic regulation the most desirable heat value can be uniformly maintained.

The use of furnace gas or mixed gas for the heating of coke ovens makes a larger amount of the richer coke oven gas available for outside use, as for instance, municipal heating and lighting. The higher and more constant heat value of the mixed gas also solves the problem of efficient gas engine operation in large electric power plants, where uniformity of speed is the first requirement.

Slag as a By-Product.

Many blast furnace slags can be used for the production of cement, an industry which has been developed to large proportions in this country and abroad. Another profitable outlet for the slag, frequently found in Germany and undoubtedly applicable to many plants in this country, is the manufacture of high grade building brick.

Possibilities of Labor Saving.

The increased output of modern furnaces, coupled with the many labor saving improvements, has lowered to a remarkable extent the cost of operation per ton of iron. The vast array of common labor which formerly performed the hardest, roughest, and most dangerous duties around a blast furnace, has been eliminated, and their places have been taken by fewer men of higher skill. The operation of charging our furnaces has reached such a remarkable degree of perfection that one man is able to fill a 500-ton stack and do it with greater accuracy, better control, and less physical effort than the host of men formerly required.

Suitable hearth construction has decreased the daily number of casts. At several plants only four casts are made in twenty-four hours. At the South Works three casts per day is the rule, 150 to 200 tons and more being tapped at a time. It is quite possible that in the future, with further enlargement of the crucible, no casts will have to be made on the night turn. Big ladles and mixers of large capacity are indispensable in this development. The latter have the further advantage of eliminating the most objectionable and wasteful part of blast furnace operations—the casting

in sand beds or pig machines and the remelting of a considerable portion of the product. In Germany some plants to-day have a sufficient mixer capacity to hold all the Sunday iron for direct conversion.

THE HUMAN ELEMENT.

To achieve uniformly good practice nothing is more essential than the building up of an intelligent, watchful and active furnace organization. The close co-operation of the foreman and the crew is needed to control efficiently every step in the operation. So much depends on correct discernment and quick action that an alert crew will in a day's work avert many troubles. Being continually in close contact with the furnace, they must be relied upon to watch the many little, yet important details of operation.

The furnace manager who fails to devote as much of his thought and energy to studying and improving his organization as he gives to correcting the design of his plant, misses one of his best opportunities. Any effort on his part to instill into his men a keener interest in the efficiency of the plant will make his task the easier. He should not hide his practice but should display the daily, weekly and monthly results in all their details, so that his men, from the constant observation of these, will derive a better understanding of their work and become more capable of doing it justice. By also giving them the opportunity to study rival plants, the incentive to greater effort is further stimulated. In no branch of industry is the exchange of experience more helpful and necessary to progress than in blast furnace work. And this method should be applied not alone to the management. Modern mechanical appliances have raised the standard of the men employed around a furnace; to keep their intellect alive and bent to their work is the command of economy and progress. Some of the best suggestions for improving operation and construction are obtained from the rank and file of the organization.

A crew convinced they are treated fairly and justly and that their employer takes an interest in their welfare, will

perform their duties willingly and cheerfully, and therefore efficiently. The welfare work now carried on by the steel industry is bearing abundant fruit. With the assistance of modern engineering and the safety campaign, it has not only succeeded in making the blast furnace plant, which in former days abounded in dangers, a safe and healthy place of work, but has exercised a most beneficial influence on the spirit and progressiveness of blast furnace organizations, especially where safety matters have been referred to the workmen themselves for suggestions and improvements of their own invention.

The betterment of the human element, which enters into every step of the process from the mining of the raw materials to the casting of the molten product, perhaps does not stand out as strikingly as the more apparent results achieved by modern engineering; yet great progress has in recent years been made in this direction, and the good results obtained in modern blast furnace practice are in no small measure due to the better spirit and greater intelligence of the workers.

OPPORTUNITY FOR PROGRESS.

In every art and industry the living generation, having reached a certain goal, is prone to believe that no further progress is possible. At the present time, with furnaces producing 500 tons and more daily from difficult ore mixtures, with fuel consumptions which we think closely approach the low limit, we may not see our way clear to further improvement; yet the possibilities are now as great as ever. Perhaps they lie in another direction, and we need not be discouraged if we fail to develop the 1,000-ton furnace or are unable to lower our past fuel records.

Our problem, I am convinced, is to reclaim and put to use those vast bodies of ore and coal which, owing to their adverse character, have in the past not been available for the manufacture of iron. This is by far our greatest task, a task which has the highest economic value in substantially contributing to our country's wealth.

The magnitude of the unit with which we deal, the large responsibilities involved, the long period of time which must elapse before new ideas are approved by practice or condemned, the many disappointments with which all of us have met, are bound to make us cautious and conservative. Yet in this age, where science and engineering have put at our command resources undreamed of by our predecessors, we will, I trust, in the daily drudgery of making pig iron, keep sight of our wonderful opportunities and do our share in advancing the blast furnace art.

MODERN AMERICAN BLAST FURNACE PRACTICE

JOHN N. REESE

General Superintendent Northern Furnaces, Republic Iron & Steel Company, Youngstown, Ohio.

Mr. Brassert has given the blast furnace fraternity considerable data and has opened up a number of new avenues of thought and investigation.

DISTRIBUTION OF RAW MATERIALS.

The proper distribution of the raw materials in the blast furnace has received the attention of blast furnace men of all time, but the problem cannot be said to have been fully solved even in this scientific age. If any proof of this assertion is needed, one has only to examine the patent office records or to make a list of the different kinds of distributing devices in use in this country and abroad. None of the various designs has proven its superiority over all others.

The ideal blast furnace top must:

(1) Be flexible, so that it can take care of any changes in the character of the materials charged and can be made to meet changing conditions of operation.

(2) Be simple and strong, so that it may be easily handled and may require little attention, and so that breakdowns may be few and easily repaired.

(3) Have a gas seal.

(4) Have a means of charging coke with the least possible breakage and abrasion.

(5) Give proper distribution of the raw materials on the large bell and at the furnace stock line.

Proper distribution is the placing of the ore, coke and limestone in the furnace so that the mass will have the same permeability to the ascending gases throughout all its sections and will descend smoothly and evenly to the hearth.

When these two essentials are assured the loss of carbon by direct reduction and by solution in the CO_2 of the gas will be at a minimum and good economical working will result.

There are many things outside of the distributing device itself that can render the distribution faulty.

Some of these influences are:

(1) Ore sticking to, and faulty balance of, the large bell.

(2) Side thrust, swinging and improper lowering of the large bell.

(3) Wearing of the stock line or change in the stock line due to the breaking or distortion of the protecting devices.

(4) Improper location of the downcomer openings, so that stock falls into them causing channels to form below each opening due to segregation of the lumps into columns.

(5) Downcomer openings too small in area or too few in number, causing the gas to channel and to carry off a large amount of fines into the downcomer.

(6) Carrying the stock line too far below the bell, making the size of the bell too large, and also causing unnecessary breakage of the coke and packing of the stock.

(7) Shifting of the furnace top relative to the furnace center, caused by warping, expansion or contraction.

(8) Warping and burning of the bell or hopper.

(9) Lack of care and watchfulness on the part of the operator.

(10) Bad weather conditions.

There are three types of blast furnace tops which are in more or less successful operation:

A. Stationary.

B. Revolving, at top of furnace.

C. Bucket revolved at bottom of furnace.

Stationary Tops.

The stationary top can be adapted to either the single or double skip. It usually consists of a receiving hopper, surmounting a cylindrical or elliptical throat with the bottom part drawn in and closed by a small bell. Considerable experimenting must be done to adapt the stationary top to

a certain set of conditions, if these conditions are materially changed the arrangement of the top must be modified accordingly. Overtravel and improper dumping of the skip affect distribution. If the central sleeve and rod are used to support the two bells there is a tendency for the fines to remain on the side beneath the skip.

The stationary top has the simplest mechanism, costs less to operate than other mechanical tops and has given successful results. A number of these tops are in use on large furnaces, but the newer furnaces show a marked tendency to adopt one of the other types.

Revolving Tops.

Revolving tops are of several kinds, differing principally in the method of discharging the materials upon the large bell. The four leading types are:

(1) Brown.
(2) Baker-Newman.
(3) Roberts.
(4) McKee.

The Brown top consists of a chute suspended to the receiving hopper, which is revolved about 86½° by the skip as it returns empty down the incline. The mouth of the chute is closed by a flap door as the large bell opens.

Experience with two of these tops on furnaces using entirely different raw materials has shown the following faults: The stock, as it slides through the chute, crowds the side opposite the skip. This occurs in a greater or less degree with every position of the top except when it points directly toward or away from the skip.

Several methods of removing this fault have been tried, such as dumping the skip very slowly, increasing the size of the charge, and narrowing the mouth of the chute; but none of them have overcome it.

The trouble may be stopped by causing the material to enter the chute centrally, by introducing a small bell and making a sort of combined Brown-McKee top, or by placing a receiving hopper with conical bottom between the skip and chute. This, however, increases the drop to which the coke is subjected.

The advantages of this type of top are its simplicity, lightness of construction and speed of operation.

The Baker-Newman top consists of a receiving hopper with a cylindrical throat closed by a small bell. A distributing or deflecting plate is attached to the bell rod. The bell and plate revolve about 87½° as they move upward and as the skip leaves the top of the furnace. As the top is usually operated the bell and plate are down when the skip dumps its load.

With this top there is less tendency for unequal distribution or separation of lumps from fines. If anything happens to the revolving mechanism of either, however, the furnace must be stopped until repairs are made or filling on one side must be resorted to. Both have the advantage of allowing coke, sand or scrap to be filled at certain points if necessary.

Some objections have been raised to the placing of the stock in piles on the large bell instead of in an even ring.

The McKee top consists of a receiving hopper, a cylindrical or slightly conical throat closed by a small bell. In some of these tops an inverted conical apron is introduced below the small bell, which throws the stock towards the apex of the large bell.

The method of operation is not the same at all plants, the difference being mainly in the number of skips dumped at certain points of distribution and in the number of points.

Revolving Bucket Device.

The Neeland or Duquesne top consists of a cylindrical bucket narrowed at the bottom by a conical section and closed by a small bell. The larry car dumps directly into the bucket, which is revolved to bring the high side of the load on the quarters. It is then hoisted to the top of the furnace where the bucket seats on the gas seal and dumps its contents onto the large bell.

Some trouble has been experienced at several plants with the small bell that closed the gas seal so that a slide has been introduced. The advantage of this slide is that

it leaves the seal entirely free for the lowering of the small bell and prevents the bell lever cutting the stock.

The Neeland device removes the revolving mechanism from the top of the furnace, allows the distribution in each bucket to be inspected, and if anything happens to the revolving machinery fairly good filling can be accomplished by leveling the contents of the bucket by hand while repairs are being made.

A number of other devices have been patented and several have been installed but those described have withstood the test of time and are in more or less successful operation.

The following table gives a census of the different tops used in the Mahoning and Shenango Valleys at the present time:

Hand Filled	16
Stationary	10
Neeland	7
Brown	4
McKee	4
Kennedy Revolving	1

The newer installations have been equipped with the Neeland top.

At several plants other types of distributors or deflectors have been installed. I refer to the Killeen and McDonald distributors.

The Killeen distributor consists of a stationary apron hung below the hopper between the inwall and the large bell The stock strikes the apron causing the fines to be deposited in an annular ring below it while the lumps form a ring next the wall and a column in the center.

The McDonald distributor produces the same result and differs from the Killeen only in that the apron can be raised or lowered as desired and the fines placed near the walls or in an annular ring below the apron. It is claimed that the walls can be kept clean by the use of these distributors.

Advantage of Single Large Bell.

The single large bell still remains the favorite with the vast majority of blast furnace managers. The present tend-

ency is to have a rather large bell, especially for fine ores, depositing the fines close to the walls and allowing the lumps to rebound and roll, forming a comparatively loose column in the center.

The proper size of bell for a given stock line diameter has been worked out from long experience with Lake ores, but there is still some difference of opinion. The rule was to allow an annular space of about two feet between the bell and the stock line, but a later rule is to make the bell so that the square of its diameter is equal to or slightly greater than one half the square of the stock line diameter.

The reason for the better results with the large bell in charging fine ores are:

(1) Owing to the comparative smoothness of the brick-work and the loosening effect of the friction between the stock and the wall, the gases have a tendency to follow the walls. Placing the fines close to the walls counteracts this.

(2) The stock in the center of the furnace travels faster than along the walls due to the friction against the bricks and the resistance resulting from the narrowing of the bosh walls, as well as on account of the loose nature of the materials in the central column. So there is a tendency for the fines to work from the walls into the interstices in the central column. This causes the mass to become more nearly of the same permeability throughout and therefore, aids the the proper distribution of the gases.

The distance below the bell that the stock line is carried has a direct bearing upon the distribution. The greater the distance, within a certain limit, the greater the tendency to deposit the fines toward the walls. The bad effect of too small a bell can sometimes be overcome by dropping the stock line a short distance.

Stock line protection is a vital part of good distribution, because wearing of the walls at the stock line or warping of a protecting device can upset the distribution of the best possible top.

MODERN AMERICAN BLAST FURNACE PRACTICE

Arthur J. Boynton

Superintendent, Blast Furnaces, The National Tube Company,
Lorain, Ohio.

In the paper which Mr. Brassert has just read he has given us a very complete and correct idea of the requirements for the successful manufacture of pig iron, and has stated that increased efficiency is the problem of to-day. During the past few years a very prominent part of the effort toward greater efficiency at the steel works furnaces with whose practice I am familiar, has been in the attempted use of acid slags and higher blast temperatures. These two features of practice are related, not merely because the one cannot be used to the fullest extent without the other, but also because they increase the fuel efficiency of the furnace in the same way, the hot blast by increasing the combustion temperature of the gases in the furnace, and the acid slag by decreasing the temperature necessary for the operations of the hearth. The advantage of hot blast is not altogether and perhaps not chiefly in the heat which it carries into the furnace but in the combustion temperature which it produces. That the effect of the increase in the difference between combustion temperature of gases and melting point of slag is much greater than that due to the amount of heat carried in by the blast has been clearly pointed out as a reason for the effectiveness of both hot blast and dry blast. Similarly the economy of acid slags is not determined entirely by the quantity of heat required to melt the slag but also by the temperature of melting.

Increase in coke consumption and the corresponding decrease in tonnage does not, however, by any means represent the sum total of the disadvantages of running with a basic slag. Such a slag carries too little silica to absorb the lime present in the region of the top of the bosh. The

lime is consequently rejected by the slag at this point and some of it remains as the chief cause of scaffolds on the bosh. The serious consequences of the formation of these scaffolds are well understood, and include irregular iron, excessive production of flue dust and interrupted operation.

Practice With Acid Slags and High Heats.

The requirements for the use of acid slags and high blast temperature are not easily fulfilled. They include correct furnace lines, uniformity of raw materials, since the furnace heavily burdened and running on an acid slag is extremely sensitive to variations in the charge, low sulphur content in the coke, correct distribution, and stove equipment to generate the temperature required. It is seldom that all of these requirements are fulfilled. Consequently, in many cases where the use of acid slags and high heats has been attempted, no consistent increase in burden was possible, and the results have been chiefly noticeable in iron alternately too hot and too cold, and in the presence of scouring slags, together with an undue wearing of the lining through the elevation of the temperature at any given level inside the furnace.

Mr. Brassert has spoken in detail of the development of furnace lines and the necessity of uniformity in raw materials and has also stated that the volume and basicity of slags are generally determined by the duty of sulphur elimination. The ability of any slag to remove sulphur at any given hearth temperature depends on its basicity, which is generally taken to be the ratio between the sum of the lime and magnesia and the silica. Any attempt to classify the sulphur holding ability of the slag in accordance with the sum of the silica and alumina is likely to show confusing results where there is much variation in the alumina.

A comparison of Bessemer slags made at Lorain, covering 120 furnace months, shows a gradual increase in sulphur content as the basicity increases. The most acid slag carries 1.64 per cent. sulphur, and the most basic over 2 per cent. The slags range from 37 per cent. to 32½ per cent. silica, and from 1.2 to 1.5 ratio of bases to silica. The

unit taken is the average composition of the slag from one furnace for one month.

TABLE SHOWING SULPHUR CAPACITIES OF BESSEMER SLAGS.

Furnace Months	SiO_2	Al_2O_3	Sulphur	Ratio of Bases to Silica
20	37.07	13.57	1.64	120 to 125
16	36.45	13.16	1.67	126 to 130
22	35.07	14.02	1.83	131 to 135
18	34.33	14.12	1.90	136 to 140
28	33.50	14.13	1.96	141 to 145
15	32.38	15.07	2.03	146 to 150

The advantage of running on the more acid slag is indicated by the coke practice corresponding to these averages, the average coke consumption for 20 months with the most acid slag being 1,922 lbs. per ton and for 15 months with the most basic slag 2,269 lbs. per ton.

LIMITATIONS IMPOSED BY SULPHUR IN THE COKE.

Where a consistent removal of sulphur is specified, few of our blast furnace plants have been in a position to avail themselves of the advantage of acid slag on account of the amount of sulphur in the charge, almost all of which is contained in the coke. With an ore supply containing 7½ per cent. silica and 2,000 lbs. of average Connellsville coke the normal slag volume is a little over 900 lbs. per ton of iron. With an acid slag capable of carrying not over 1.64 per cent. sulphur at the hearth temperature when on Bessemer iron, the limit of sulphur in the coke for the normal slag volume is .8 per cent.

At the hearth temperature of a furnace making basic pig iron, with the same kind of slag, where the silicon is determined by the hearth temperature, the sulphur content of the slag will be about 1.2 per cent. This sulphur capacity in the slag requires sulphur in the coke below 0.6 per cent. for the normal slag volume. Any increase in sulphur in the coke above these points must be met in one of two ways, either by increasing the basicity of the slag or by increasing its volume.

With a sulphur in the coke of 1 per cent. the additional

slag would be 300 lbs. in Bessemer practice and 700 lbs. in basic. A voluntary increase in slag volume to the amount of this latter figure would probably be considered very poor practice. The additional cost for the three principal items of increased coke, increased limestone and increased operating cost due to lessened tonnage would amount to about sixty-seven cents per ton of iron, all of which can be more or less accurately calculated; while the losses due to running on basic slags cannot be calculated with any certainty. The fact that the blast furnace man is required to choose between these evils emphasizes the importance of determining the cost of coal washing and its application wherever practicable, as well as the maintenance of a constant sulphur content in any grade of coke by a local grading similar in principle to that used in the case of ores.

Distribution of the Charge on the Bell.

Aside from furnace lines and quality of raw materials, nothing has greater effect on the ability to carry heavy burden than the distribution of the charge on the bell.

Some years ago we made, at Lorain, a series of experiments continuing over some months, first with small models and afterwards on the full scale. These experiments showed the extreme difficulty of obtaining in a skip-filled top, with materials differing from each other as widely as coke and stone differ from ore, a distribution which is correct by weight and also with respect to proportion of coarse and fine material on each quarter of the bell.

Mr. Brassert, in his paper, has clearly stated the importance of an equal subjection of all parts of the charge to the action of the furnace gas as a matter of fuel economy. That more or less direct reduction takes place as a result of relatively greater compactness of the charge on one side of the furnace is unquestionable. Even where high blast heat can be applied to remedying this condition, it is still to some extent a waste of the hot blast,—applying it to do work in the hearth which should have been done above. In many cases a limiting condition to the use of hot blast is found in this cause, inasmuch as a furnace with even slightly im-

proper distribution reaches the limit of burden on one side only. Bad distribution is also a very frequent cause of excessive production of flue dust, a condition for low production of which is the continuous and uniform movement of the charge practically as one mass. Experience has shown that with such a movement a relatively slight production of flue dust takes place, and that it is not the average velocity of gases in the top but the excessive velocity due to slips which throws over the dust. The margin of velocity, however, is so slight that even very slight slipping will greatly increase the dust production. Uniform movement of the charge can only take place with perfect stock distribution. Any other distribution will result in a movement which may be steady on one side and intermittent on the opposite side, resulting in more or less of a vertical shearing of the charge which is a most usual cause of excessive flue dust.

The fact that good practice under favorable conditions has been made with a distribution that is not perfect is not, in my judgment, a good reason for neglecting the utmost possible refinement in distributing the charge. This refinement should include, in the case of skip-filled furnaces, the experimental determination of the best possible proportions of receiving hopper and throat, and of the position, angle and speed of dumping of the skip car; the removal of all obstructions to the flow of stock, such as crossheads for supporting the main bell, and lifting and holding lugs cast on its surface; a sufficient slope, probably not less than 50° for the main bell, and the machining of its entire surface; the absolute centering and alignment of every part of the charging machinery with the furnace; the governing of extent and speed of travel of the bells, and the rotation of the charge in the throat. With regard to this last feature it should be noted that, even though it is possible under any carefully observed set of conditions to effect a perfect distribution in a stationary top, the conditions of operation, including variation in the proportion of coarse and fine material in the coke and limestone, and of the water in the ore, together with the practical impossibility of maintain-

ing the angle and speed of dumping constant at all times, will result in an error which we cannot afford to overlook. The rotation of the charge is by no means a cure-all for imperfect distribution, but it seems to me to be essential to the high degree of refinement which is necessary for the best possible practice.

The advantages of running with a high blast temperature when the establishment of the conditions referred to above has made its use easy and natural, are well understood and generally admitted. In saying this I have in mind not so much the use of excessively high temperatures as a general increase in the temperatures now in use, which average between 900° and 1,000°. However, the prospect of working with leaner ores and higher slag volumes makes it seem probable that an increase beyond the highest temperatures now regularly used may be expected, since it is generally true that in districts where lean ores have to be smelted, the average blast temperature is much higher than it has been in the district using Lake ores. The question of stove capacity and design is, therefore, of much interest.

Stove Capacity.

The average stove capacity of our furnaces 21′ 6″ and over in bosh diameter is about 175,000 sq. ft. of heating surface, distributed in almost every case among four stoves. These stoves are generally of the two pass side combustion or three pass type. The consideration which has governed the size of these stoves has been primarily ability to get the temperature desired, seldom over 1,200°, even for short periods of time. The details have been governed largely by considerations of structural strength and facility of cleaning. Most of the two pass stoves are built with nine inch checker openings and three inch walls. The three pass stoves generally have four inch walls and an average size of checkers not less than those of the two pass stoves. Aside from the question of cleaning, and with the object of gaining as large heating surface as possible inside a given shell, the thickness of the checker walls should be as small as strength will permit, and the openings the same diameter

as the checkers. With three inch walls, a reduction in the diameter of the openings from nine inches to six inches will increase the surface about eighteen per cent., and a reduction to four inches about thirty per cent. With a two and one-half inch wall and four inch openings the increase in surface is over 51 per cent. By changing their size it is therefore possible where washed gas is available to make a very considerable increase in the capacity of the stove without increasing the radiating surface of the shell, and this fact forms one of the strongest arguments for the use of washed gas. With unwashed gas the percentage of increase of surface which it is practicable to make is relatively small, since six inches in diameter of opening is generally considered the smallest advisable.

TABLE SHOWING SURFACE PER CU. FT. VOLUME AND BRICK PER CU. FT. VOLUME IN VARIOUS SIZES OF CHECKERS.

Thickness of Wall	Diameter Opening	Surface in Sq. Ft. per Cu. Ft. of Volume	Per Cent. Increase	Cu. Ft. Brick per Cu. Ft. Volume	Per Cent. Increase
3 in.	9 in.	3.000	....	.438	..
3 in.	6 in.	3.556	18.5	.556	27
3 in.	4½ in.	3.840	28.0	.644	47
3 in.	4 in.	3.918	30.6	.674	54
2½ in.	4 in.	4.544	51.5	.621	42

Aside from increase in surface there are other advantages of small checkers, due to the changed ratios of surface to volume, which result in much greater intimacy of contact between the air or gas and the brick work, and a much better economy in a stove of any given height.

TABLE SHOWING RATIOS OF SURFACE TO VOLUME IN SQUARE CHECKERS OF DIFFERENT SIZES.

Diameter of Square Checker Openings	Height of Checker	Surface Sq. Ft.	Volume in Checker Cu. Ft.	Ratio of Surface in Sq. Ft. to Volume in Cu. Ft.
3 in.	1 ft.	1,000	0.0625	18 to 1
4 in.	1 ft.	1,333	0.1109	12 to 1
4½ in.	1 ft.	1,500	0.1409	10.67 to 1
6 in.	1 ft.	2,000	0.2500	8 to 1
9 in.	1 ft.	3,000	0.5625	5.33 to 1

From this table it appears that the surface in contact with any volume of gas or air varies inversely as the diameter of the checker opening.

From the relations shown it is evident that in a pass of a given length, the surface to which any given amount of air or gas is exposed in traveling through the pass at a given speed is also inversely proportional to the diameter of the checker opening.

It follows that in order to get the same relation between surface and volume in a nine inch checker as in a four and one-half inch checker it is necessary to reduce the speed of the gas or air one-half, or double the height of the stove.

The method of increasing the stove capacity will vary at each plant in accordance with the size of existing stoves, the final determination of minimum dimensions in the checkers and the number of square feet required. A lower limit of three inches in the thickness of the checker walls and four inches in diameter of opening will barely enable the small 21′ x 100′ two pass stoves to reach the present capacity of the larger three pass stoves, four of which run a little below 200,000 sq. ft., and any increase above this figure will require additional height or a fifth stove. The capacity of the 22′ x 100′ three pass stoves can be increased over 30 per cent. by the use of three inch walls and smaller openings.

A recent description of a German method of forcing the air for combustion of gas into the stoves, and the consequent ability to run the furnace with two stoves, one on air and one on gas, has attracted some attention in this country. Comparison shows, however, that the four stoves in question which were operating on a furnace making 168 tons of iron per day were as large as the stoves of some American furnaces making 500 tons per day, and that with only half this equipment in use the square feet of heating surface per ton per day, and probably per volume of air blown remains greater than is the case at most American furnaces. The so-called "forcing" is, therefore, not forcing according to our standards.

In conclusion it may be said that successful blast furnace

practice is well known to consist in the proper adjustmen to each other of a great number of details, none of which is too small to have a bearing on the general result. Our technical literature of the blast furnace is largely made up of studies of separate details, each considered more or less by itself. The completeness with which these details have been enumerated and their relations to each other described, is a peculiar and valuable feature of Mr. Brassert's contribution of to-day.

MODERN AMERIÇAN BLAST FURNACE PRACTICE

Richard V. McKay

Superintendent, Blast Furnaces, Pennsylvania Steel Company, Steelton, Pa.

Mr. Brassert's statement that, "with more and more difficult raw materials, progress is not so much in the direction of new records of production and fuel consumption, as in the ability to maintain the best results of the past in the face of greater handicaps," has particular application to the progress made during the last six years in developing the practice of smelting the high alumina Cuban ores in the blast furnace. The fundamental conditions have been somewhat different as to progress made in Mesaba, compared with that made in Cuban ore, practice. In the latter case, it has not been a struggle to retain ground already conquered. It has rather been one of aspiring to the high standards previously set by Mesaba practice. During the entire period, the Cuban ore furnaceman has been on the under side. He has been fighting to do as good work on these ores, which in their natural condition might be termed low grade, as had previously been done on Lake ores, without ever daring to think that he could surpass the results obtained in earlier practice. All the odds seemed against him.

Progress in Developing the Smelting of Mayari Ore.

Before proceeding with a more or less detailed account of the various steps in the march toward the present very satisfactory results in smelting Mayari ore, it might be interesting to picture the obstacles, some apparent and some not, which lay in the path of the metallurgist and engineer, when the Mayari ore fields were discovered in 1904.

The deposit was enormous in extent, but it was located some two thousand feet above sea level on a plateau diffi-

cult of access, miles from the sea coast, and hundreds of miles from the blast furnaces which were to be supplied, in an almost uninhabited, insect and fever infested, district. The problem of mining was simple, but the ore contained great quantities of moisture and combined water, which necessitated drying before shipment to the States.

Nodulizing Problems.

To erect and operate an industrial plant with all the requisite accessories for this purpose in a country far from the labor and manufacturing markets was not an inviting task; yet in view of the freight saving obtainable by eliminating the water in the ore, this seemed to be the only recourse. The ore was extremely fine, and naturally, since nodulizing was but one step beyond drying, there seemed no reason why the two results could not be obtained in a single operation. This opened the immense field of nodulizing problems. Due to excessive moisture and, no doubt, partly to the high alumina content, Mayari ore was not as easily nodulized as other materials, such as Cornwall concentrates, pyrite cinder, flue dust, etc., upon which much experience had previously been gained. Preliminary experiments were conducted with Mayari ore in a nodulizing kiln at the Lebanon Plant of the Pennsylvania Steel Company. These experiments indicated that there was no apparent difficulty in forming nodules, nor was the fuel consumption excessive. However, when the somewhat larger kilns, designed for greater capacities, were placed in operation at Felton, Cuba, with the best labor available, which was none too good, it was discovered that there were many lessons yet to be learned. Extensive mechanical changes were necessitated to adapt the plant to tropical conditions. Machinery which was at all complicated, or which required intelligence in operation had to be eliminated as far as possible, for the Cuban and imported labor proved quite unreliable.

Besides this, Mayari ore in the raw state was handled with great difficulty, due to its sticky, clayey consistency, and the original bucket elevators and conveyors gave way

to gantry cranes and grab buckets. In the raw state, the ore would stand in a pile at a ninety degree angle, and even when grab buckets were installed, the question of handling was not entirely solved. This physical condition of the raw ore gave no end of trouble in obtaining regular feed to the kilns. Various constant feed devices were tried, until the present revolving platform feed was determined upon as the best to meet the conditions. Had the plant been located within easy reach of a manufacturing center, all of these difficulties could have been corrected within a short time and at fairly small expense, but since it was necessary to build all machinery in the States and ship it to Cuba, months were consumed, where under similar conditions in industrial plants more favorably located, it would have been a matter of days.

From the first, in nodulizing Mayari ore the fuel consumption and the quality of nodules, as far as fines were concerned, caused considerable disappointment, although it was expected that slightly more fuel would be needed than experience with other materials had established. The question of obtaining complete combustion, together with that of transmitting most effectively to the ore the heat generated; the diminution of heat losses; the recovery of lost heat; experiments to facilitate nodulizing and increase the size of nodules by additions of foreign substances, by reducing the melting point, and otherwise—all these constitute but a few of the items which have been consuming the time and thought of the metallurgist.

Concerning the quality of nodules produced, it was assumed at an early date that 90 per cent. remaining on a 40 mesh screen would be satisfactory for blast furnace use. This size was assumed on the basis of Lake practice, the idea being to get ore somewhat coarser than the Mesaba ores. With this standard set, operations at the Felton plant were brought to a fairly satisfactory basis. Kiln tonnages were increased gradually to a maximum of nine tons per hour and at the same time fuel consumption was reduced. However, the quality of ore produced gave excessive flue dust losses in the blast furnace, and it was found

necessary to make a new standard of 75 per cent. material remaining on a 10 mesh screen. This more recent standard resulted in reducing the kiln tonnages and increasing the fuel consumption, but by using binders in the nodulizing process satisfactory results were obtained. Since successful blast furnace practice demands the coarser nodules, future advances in Cuba will be made upon this basis.

Blast Furnace Problems.

Following the nodulizing problems came those of the blast furnace. Uncertainty centered about the behavior of a furnace carrying such high percentages of alumina in the slag. There was no precedent to guide the furnaceman and naturally he had to be extremely cautious. In September and October, 1904, experiments were conducted on a small furnace at the Steelton plant of the Pennsylvania Steel Company to determine some facts concerning this important question. By means of Lake ore, chromite, brick bats, and bauxite, a furnace mixture was concocted approximating Mayari ore in chemical composition. The test run lasted 11 days, during which time the furnace averaged 102 tons on a one to one fuel ratio. This mixture worked with sufficient success as to the character of the slag and the general furnace conditions, to warrant a small shipment of ore from the Mayari district. About 1,200 tons were transported on mule back from the deposit at El Perio to the sea coast, and shipped to Steelton, where it was tried with more or less success on No. 1 Furnace in February, 1906. This test was of six days' duration, the furnace averaging 59.5 tons of iron per day on a fuel ratio of 2.13. The flue dust was excessive, however, and as a result the actual yield of pig iron was but 29 per cent.

Notwithstanding the unfavorable results as to fuel ratio and yield, the fact was established that the alumina content of the ore presented no insurmountable difficulties, but it was conceded that the physical condition of the ore would require considerable attention. Further shipments of raw ore, and later nodules, were made to the States and converted into iron from which the steel maker had an oppor-

tunity to test his skill in the elimination of chromium. Suffice it to say that the troubles of the open hearth and Bessemer man were many, but this phase of the Mayari problem was worked out economically far in advance of the blast furnace difficulties.

Unlike the conditions which surrounded the development of Mesaba practice, experimentation on the Mayari ores was confined to the resources and equipment of one company, and was conducted with the use of coke, generally speaking, of an inferior quality and with a limited corps of furnace operators. With but two plants available for experimentation, and these not equipped for handling such varied conditions while conducting their routine business, progress was naturally slow. Problems had to be solved one by one, and at such time as not to interfere with the regular output of iron and steel.

Peculiar Characteristics of Mayari Ore.

Before proceeding further, it might be well to describe in a general way this ore which has recently become such an important addition to the iron ore resources available to the steel industry of the eastern United States. The enormous deposits in northeastern Cuba can be mined at a cost which can be duplicated elsewhere only under exceptional circumstances. The heavy mantel of Bessemer grade ore, ranging in thickness from one foot to eighty feet and averaging about eighteen feet, with absolutely no over burden, covers a plateau of serpentine bed rock. From this it originated through a process of rock-disintegration and decay.

As mined, Mayari ore has approximately the following chemical composition:

Fe.	H_2O	SiO_2	Al_2O_3	Mn.	P.	S.	Cr.	Ni.	Combined water
38.14	23.22	2.00	10.00	.51	.013	.15	1.46	.57	11.50

It consists of a mixture of hydrated iron oxide, limonite, with hydrated aluminum oxide, bauxite, and the oxides of nickel, chromium, and cobalt. In appearance the ore is a reddish yellow to dark red in color, and is of a decidedly clayey consistency.

The following table gives the results of a sizing test made on the raw ore after it had been thoroughly dried. This will indicate the extreme fineness of the ore. For comparison, I have placed beside this the screen test of Mesaba ore which Mr. Brassert gives in his paper.

Ores	Screens							
	No. 2	No. 8	No. 20	No. 40	No. 60	No. 80	No. 100	Through 100
Mesaba......	25.40	26.86	12.54	10.86	6.92	2.76	3.34	11.33
Mayari (Raw)	0.00	27.72	34.36	18.93	6.03	4.07	1.05	7.84

Pretreatment of the Ore Necessary.

It is true that experience with Mesaba ores served as a precedent and demonstrated that it was possible to smelt very fine ores economically in a blast furnace, but perhaps this fact misled rather than guided those who were working to solve the mysteries of Mayari ore. As a consequence, much valuable time was wasted in trying to make a furnace digest the raw ore with its 20 to 25 per cent. hygroscopic moisture and 11 to 13 per cent. combined water. However, to counteract this tendency, the desire to save freight charges on shipments of useless water from Cuba to the States immediately suggested the use of some type of dryer. Then too, although furnaces were operated on high percentages of the raw ore, the excessive losses of iron-bearing material as flue dust, the consequent low yield of iron and nickel, and the uneven working of the furnace caused by slips and explosions, made the process uneconomical and indicated at an early stage that some method of preliminary treatment must be resorted to in order to agglomerate the ore and make it suitable for the blast furnace.

With large percentages of raw Mayari ore in a furnace mixture, violent slips occurred and made operations extremely irregular. Why this ore should act worse than Mesaba ores in this respect in passing through the furnace has been a question to which furnacemen have given a great deal of thought. Perhaps the most logical explanation is that the 11 to 13 per cent. of combined water caused the trouble. No doubt, following a period during which the

furnace was hanging, the stock was precipitated into the lower zones where the temperature was high enough to drive off the combined water. The sudden generation of steam caused an explosion which gave the typical fine ore slip. These did considerable damage to the old fashioned open top furnaces used on this work, both at Sparrow's Point and at Steelton, especially at the former plant, where more experimenting was done on the larger capacity furnaces.

Nodulizing.—Considerable preliminary experimenting was done to determine the most feasible means of preparing the ore. The use of briquetted raw ore lost favor, chiefly on account of mechanical difficulties and cost of production. A machine was built for the purpose of rolling the ore into corrugated sheets which were afterwards sintered. This likewise proved expensive and did not answer the purpose. Finally, nodulizing was determined upon as the most promising method, and the erection of a plant was begun in Cuba. The fact that the Pennsylvania Steel Company already had nodulizing kilns in successful operation at Steelton and Lebanon on Cornwall concentrates, pyrite cinder, flue dust, etc., no doubt led to the use of the kiln.

The first kiln went into commission November, 1909, and the first shipment of nodules was made in December of that year. At present, the plant consists of twelve kilns; eleven, with 10 feet shell diameter by 125 feet long, and one, 9 feet shell diameter by 125 feet long, with a daily capacity of 1,500 to 2,000 tons of nodules. Numerous modifications of this process have been developed which show good results. The analysis of the nodulized Mayari ore dried at 212° is as follows:

Fe.	H_2O	SiO_2	Al_2O_3	Mn.	P.	Cr.	Ni.	S.
56.53	2.14	4.11	12.89	.71	.018	2.04	.93	...

The following table gives a comparison of screen tests made on Mayari nodules produced in Cuba on the old basis: (1) 10 per cent. through the 40 mesh; (2) coarse nodules produced in Cuba; (3) lime nodules which come up to the

new standard of 75 per cent. on the 10 mesh; and (4 and 5) typical Lake ores as shown by Mr. Brassert.

	On ¾ inch	No. 2	No. 8	No. 20	No. 40	No. 60	No. 80	No. 100	Through 100
(1) Fine Mayari Nodules.......	4.70	2.40	31.80	25.50	21.53	6.76	2.95	1.16	3.20
(2) Coarse Mayari Nodules......	8.75	4.15	44.42	22.34	13.31	3.45	1.46	.49	1.63
(3) Coarse Lime Mayari Nodules.	28.45	10.98	41.15	11.75	5.35	1.02	.43	.10	.77
(4) Mesaba ore.....	.....	25.40	26.86	12.54	10.86	6.92	2.76	3.34	11.33
(5) Old Range ore..	.....	30.16	30.76	15.01	8.14	4.16	2.06	2.74	7.01

NOTE—For comparative purposes, on account of the use of a different screen scale, the 10 mesh screen used in our tests is counted as No. 8 as used by Mr. Brassert.

Using the nodules as shown in test No. 1 in a 300-ton furnace with 75 per cent. in the mixture, 10 to 20 per cent. of flue dust was made. With 75 per cent. of coarse nodules in the mixture in such a furnace, the flue dust should drop to 5 per cent.

The question immediately arises as to why the flue dust loss with fine Mayari nodules is so much greater than with the relatively finer Lake ores. This is probably to be explained by the fact that the nodule particles are more free and granular than in the Lake ores and no doubt retain this condition to a greater depth in the furnace due to the absence of any great amount of carbon deposit in the upper zones of the furnace. Laboratory experiments, made by passing blast furnace gas over samples of Mayari nodules and "Admiral" Lake ore under identical conditions of temperature, showed maximum carbon deposit of 157 per cent. at 450° C. with "Admiral" ore against a maximum carbon deposit of 0.7 per cent. at the same temperature with Mayari nodules. This condition is perhaps somewhat modified in the blast furnace, yet it is possible that it affects the tendency of the two ores to pass off in the gas as flue dust.

Sintering.—A considerable tonnage of Mayari ore in the natural state has been sintered in Greenawalt pans by ad-

mixture of furnace flue dust which furnished the combustible material, but up to the present time, the sintering of this ore with the addition of coal, coke, or other fuel has been conducted only on an experimental basis. Mixtures of anywhere from one-quarter flue dust (15 to 18 per cent. carbon), with three-quarters raw ore, down to three-quarters flue dust with one-quarter raw ore have given good results. Eight to ten per cent. of fine anthracite coal, culm or coke breeze mixed with the ore gave a good sinter when tried experimentally. Bituminous coal did not work satisfactorily as the hydro-carbons, tar, etc., volatilized from the coal in the burning portion of the charge condensed in the pores of the cold and wet portions, thereby closing up the air passages and causing dead unsintered spots. The sintering process promises to prove the most efficient means of preparing Mayari ore for the furnace.

Briquetting.—Attention has been paid to application of the Mashek briquetting machine to the treatment of raw Mayari ore. This machine in its present form consists essentially of two corrugated rolls, with the corrugations running parallel to the axis of the rolls, on the surface. These rolls are held together by powerful springs which exert pressure on the ore as it is fed between them. Pencils of compressed ore approximately twelve inches long and one and one-half inches in diameter result, and it is hoped that these will hold together till they pass down into the furnace, or if they do break, will not produce fines. Of course, this material will not stand weathering and consequently will have to be charged directly from the machine into the furnace. Since the cost of mining of Mayari ore is so exceedingly low, any means by which the ore may be successfully prepared for use in its natural state is sure to prove attractive. It may be found that the ore in its natural condition is best suited for reduction in a blast furnace.

Coke Conditions.

To my mind, the inferior coke heretofore available in carrying on the furnace operations has been the greatest stumbling block in the way of satisfactory progress, equal-

ling in importance the question of the size of nodules. The Maryland Steel Company was forced to use in its furnaces coke from an obsolete by-product coke plant—one of the first of its kind built in this country.

At Steelton, coke oven operating conditions were all that could be expected with a modern Semet-Solvay coke plant, but the character of the coal supplied to the ovens resulted in a coke of varying ash and sulphur content. The physical structure was weakened by layers of slate forming fracture planes, and this resulted in excessive quantities of coke breeze.

As a consequence of the use of raw coke and coke containing worthless breeze, exceedingly high blast pressures resulted. Coke dirt scaffolds formed, and then at intervals would slide in great masses into the furnace hearth. The furnace required continual checking to prevent heavy slips. When the already fine state of the stock column due to the coke, was further aggravated by the use of fine Mayari nodules, the furnace conditions grew worse. Under the circumstances, it was perhaps only natural that an undue share of the furnace troubles was attributed to Mayari ore. In other words, the extremely fine condition of the stock column due to both fine dirty coke and fine Mayari nodules has been the cause of high pressures, loss of tonnage, increased fuel consumption and practically all the other bad effects which were experienced on high percentage Mayari mixtures.

Certain developments of the last few months have cleared the horizon both at Sparrow's Point and at Steelton. Due to business conditions, all furnace operations were suspended at the former plant in January, 1914, and at that time also the old coke plant passed out, and has been dismantled. Operations were resumed in March, using a high grade Connellsville coke. Since then, normal pressures, exceptionally good fuel consumption and tonnage, and ideal furnace operations have been the rule.

Following are some records of No. 2 furnace, Maryland Steel Company, under both conditions—with old by-product coke and with Connellsville coke:

	Old Coke			Connellsville Coke		
	Sept. 1913	Oct. 1913	Nov. 1913	Mar. 1914	April 1914	May (14 days) 1914
Average daily tonnage...	316	329	302	337	427	436
Average daily fuel ratio.	1.18	1.14	1.13	1.22	1.01	0.98

Much of the good record of April and May, 1914, is no doubt attributable to the use of coarser nodules than had previously been used. That the size of the nodules is an item of great importance is borne out by practice on 100 per cent. nodulized Cornwall concentrates at Lebanon. On this ore, of a character entirely different from Mayari, it is an established rule that fine nodules result in retarding the traveling of the furnace, in abnormal blast pressures and in reduced outputs of iron.

During this same period, at Steelton, a coal washing plant was completed for the purpose of removing slate and sulphur from the coking coal. This plant began operations in March, 1914, and at once the resulting quality of coal was such as to give an excellent coke in the ovens. The washing plant has a capacity of approximately 1,500 tons of washed coal in ten hours. The analysis of the Penn-Mary coals, coke from unwashed coal, washed coal, and coke from washed coal are as follows:

	Volatile	Fixed Carbon	Ash	Sulphur
Penn-Mary Coals..............	25.00	65.63	9.37	1.80
Coke from unwashed coal......	1.29	86.07	12.64	1.33
Washed coal..................	27.51	66.17	6.32	0.96
Coke from washed coal........	0.89	90.35	8.76	0.86

The coke resulting from washed coal was of an exceptional character, physically as well as chemically, being strong and tough, with a splendid open cell structure. The results of some physical tests made on washed and unwashed coke, showing a slight decrease in specific gravity and a correspondingly slight increase in the size of cells, due to washing coal, were as follows:

	Unwashed Coke	Washed Coke
Specific gravity, apparent......	.972	.935
Specific gravity, real..........	1.812	1.798
Per cent. cells............	46.96	48.31
Per cent. walls............	53.04	51.69

The Penn-Mary coals are naturally good coking coals and make splendid coke when sulphur and ash are within reasonable bounds. This is no doubt the reason that such a slight difference is noted between the washed and unwashed coals.

Limestone.

A local dolomitic limestone, which for Lake ore practice would be considered of a very low grade, suits the Mayari practice splendidly at Steelton. It analyzes approximately 3.5 to 6 per cent. SiO_2, 69.5 per cent. $CaCO_3$, and 25 per cent. $MgCO_3$. In Cuban ore practice it has been found that 9 to 10 per cent. MgO in the slag is very beneficial. At Sparrow's Point a mixture of half calcite and half dolomite is used to obtain this condition. When calcite alone was used, trouble was experienced with foamy cinder and heavy slag runners. All stone is crushed to go through a six-inch ring, and the fines removed.

The Latest Experiments in Practice.

With ideal coke available, and with a new standard established for the coarseness of Mayari nodules, a splendid opportunity presented itself for the solution of some unsolved problems. By eliminating so far as possible all the variables the field was opened for the study of slag conditions, the internal working of the furnace and other items which might be demonstrated. With this object in view, an elaborate series of tests was begun in March, 1914, on No. 1 furnace at Steelton.

To be sure, this furnace is small, being 9 feet 6 inches hearth, 15 feet bosh, 11 feet stockline, 65 feet high, yet for experimental work it presented decided advantages. Tests of longer duration could be run on smaller tonnages of materials, and since most of the ore was especially prepared, this was quite a considerable item. It might be argued that results attained on this small furnace would not be comparable with those to be expected on a larger furnace. To meet this argument, we have previous history giving the comparative performance of this small furnace and larger

ones on other mixtures with conditions approximately alike. From earlier experience, it is fair to assume that this small furnace will run from 200 to 250 pounds higher on fuel consumption than one of the 300 ton furnaces. This is due chiefly to small size and uneconomical lines, and partly to the fact that the output is limited by lack of stove capacity and by the antiquated methods of filling. On the other hand, the flue dust production would be but half that of a 300-ton furnace.

After the blowing in on March 16, 1914, the furnace became fairly well straightened out on March 21st, when, with unwashed coke, 75 per cent. of fine Mayari nodules was put on the furnace for two days (see Chart I). Then the schedule of tests continued as follows:

Two days' run, unwashed coke, 75 per cent. fine Mayari nodules.

Five days' run, unwashed coke, 81.25 per cent. fine Mayari nodules.

Seventeen days' run, washed coke, 81.25 per cent. coarse Mayari nodules.

Six days' run, washed coke, 3 per cent. lime nodules.

Ten days' run, washed coke, high lime nodules.

Fourteen days' run, washed coke, screened nodules.

This brings us up to date and the tests are to be continued approximately as follows:

Ten days' test, washed coke, 81.25 per cent. sintered Mayari ore and flue dust.

Ten days' test, washed coke, 81.25 per cent. Mashek briquettes.

Ten days' test, washed coke, 81.25 per cent. partly dried raw ore.

Some of the points deserving especial mention as shown on Chart I. are: the sudden clearing up of the entire situation when the change was made from unwashed coke and fine nodules to washed coke and coarse nodules, showing increased product, improved yield of iron from ore, a drop in fuel ratio, a drop in the percentage of stone to ore, a reduction in flue dust produced, a remarkable drop of 3 to 4 pounds in blast pressure, an increase in the nickel content

of the pig iron, a drop in the sulphur content of the pig iron and the establishment of extremely regular, uniform furnace conditions with complete absence of any slipping or hanging. The high alumina, and high percentage of acids in the slag will be of interest.

During the entire run, the physical condition of the slag has been excellent. After flushes and casts, the runners contained practically no cinder, all having drained clean. The slag was invariably hot and exceptionally fluid. With silica plus alumina about 52 per cent., composed of approximately 29 per cent. alumina and 23 per cent. silica, good results were obtained. In fact it developed that variations in alumina from 27 per cent. to 33 per cent. and in silica from 20 per cent. to 25 per cent. had no apparent effect on the operation of the furnace. To me the temperature of the slag appeared far more important than its chemical composition. Our excellent coke gave an intensely hot hearth and no difficulty resulted in handling the slag and obtaining good iron. A slag volume of approximately 1,740 pounds per ton of iron was maintained in the various tests. A small amount of mill cinder—6 per cent. running about 29 per cent. SiO_2—seemed to help the slag conditions by increasing the SiO_2 about 2 per cent. in the slag.

The normal Mayari pig iron, analyzing about 1.00 per cent. Si., .03 S., 1.00 to 1.20 Ni., 2.00 to 2.40 Cr., presents very little grain in the fracture. This iron has as a rule a large crystalline structure somewhat similar to spiegel, although with higher silicon content and under conditions of slow cooling, it is not uncommon to find fractures exhibiting a full grain. However, the presence of chromium in pig iron seems to drive the carbon into the combined form, thus giving the spiegel effect. One great peculiarity of this iron is the high total carbon which in our recent tests averaged 4.65 per cent., and the high ratio of combined to graphitic carbon.

The results show very little if any advantage of lime nodules over straight Mayari nodules, but the chances are that the advantages of the former would be brought out to a more marked degree in a larger furnace, where the stock

	Lake Ore Dec., 1908	75 Per cent. Fine Nodules and Unwashed Coke	81.25 Per cent. Fine Nodules and Unwashed Coke	Coarse Nodules and Washed Coke	3 Per cent. Lime Nodules and Washed Coke	7 to 9 Per cent. Lime Nodules and Washed Coke	Screened Nodules and Washed Coke
Product, Tons	170.43	91.76	98.98	157.10	150.08	156.39	158.58
Actual Yield	.52	.51	.49	.59	.57	.58	.61
Theoretical Yield	.....	.59	.59	.605	.596	.581	.62
Fuel Ratio	1.15	1.43	1.49	1.15	1.18	1.15	1.13
Stone, per cent. of Ore	.....	.46	.46	.35	.33	.30	.38
Flue dust, per cent. of Ore	.....	.....	9	6	5.2	1.4	3.6
Blast Temperature, °F	735	1027	985	873	832	820	816
Blast Pressure, pounds	10	8.5	10	8	8	7⅔	8
Cubic feet Air per Min	21504	16212	18122	20482	20580	20580	20580
Chromium in pig iron, per cent.	.....	2.09	2.28	2.08	2.07	2.14	2.29
Silicon in pig iron	.....	1.48	1.40	1.06	1.01	1.07	1.24
Nickel in pig iron	.....	0.95	1.04	1.24	1.19	1.07	1.19
Sulphur in pig iron	.....	.043	.072	.041	.027	.039	.025
Sulphur in coke	.....	1.07	1.30	0.77	0.81	0.80	0.87
Ash in coke	.....	13.92	11.38	8.54	8.79	8.91	8.84
Sulphur in slag	.....	2.60	2.31	1.82	1.97	1.97	2.04
$SiO_2 + Al_2O_3$ in slag	.....	46.60	50.08	51.82	52.22	52.95	54.07
SiO_2 in slag	.....	25.70	24.11	22.58	24.19	23.81	24.30
Al_2O_3 in slag	.....	20.90	25.97	29.25	28.03	29.14	29.76
$CaO + MgO$ in slag	.....	49.76	.....	45.36	46.00	44.61	43.95
CaO in slag	.....	40.10	.....	37.44	37.51	36.68	35.94
MgO in slag	.....	9.66	.....	7.92	8.49	7.93	8.00
Ore on 10 Mesh	.....	.....	35.29	57.32	63.65	80.58	74.90
Ore Through 40 Mesh	.....	.....	15.50	7.10	5.30	2.24	6.47
Flue Dirt Through No. 10 on No. 20	.....	.....	8.18	18.13	23.45	16.73	6.22
Flue Dirt Through No. 40	.....	.....	60.75	28.83	19.77	22.09	36.61
Top Pressure, inches water	.....	.....	.....	1.2	1.25	1.14	1.17
Top Temperature, °F	.....	.....	.....	249	275	272	286
Moisture in Grains per cu. ft.	.....	2.7	3.5	2.5	4.0	3.6	4.7

NOTE—In slag analyses, the per cent. of CaO shown is slightly in error in so far as it includes the Ca as CaO which is combined with the S to form CaS.

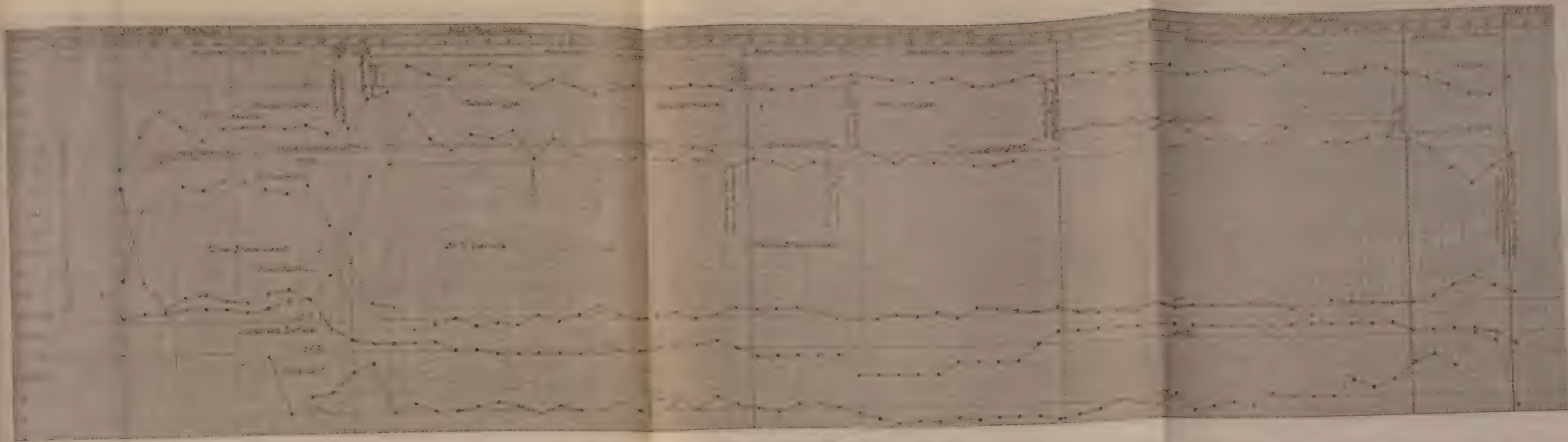
column is larger and where consequently more benefit would be derived from having the lime thoroughly mixed throughout the ore charge.

A summary of the average results from each test are tabulated on page 87, together with the data of the month of December, 1908, when No. 1 furnace made a record tonnage on a mixture of 75 per cent. Lake ore and 25 per cent. Daiquiri ore.

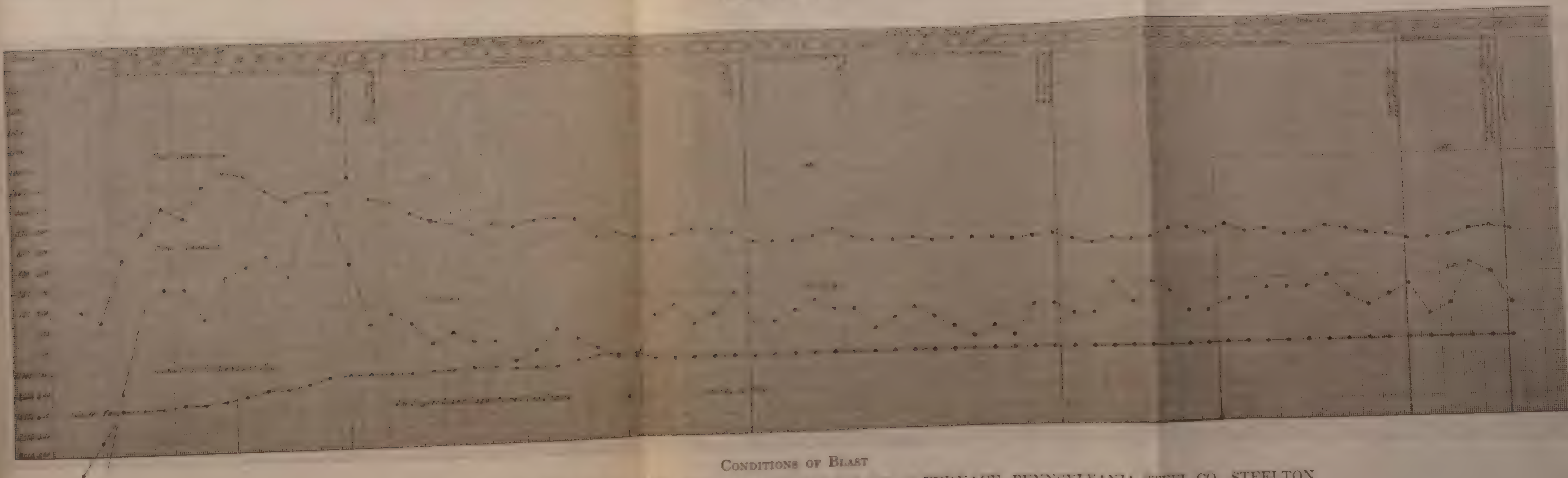
In spite of the favorable results obtained on this small furnace the great question now is, "How will a large furnace work on similar mixtures?" The results will no doubt prove better on a large furnace. This point will be demonstrated at Sparrow's Point by a conclusive run in the near future as soon as the coarse nodules arrive from Cuba. Already a short test run has been made on No. 1 furnace at Sparrow's Point, and the results were very encouraging. Following is the tabulated data covering the seven days during which more than 50 per cent. of coarse nodules were used in the mixture.

Date April, 1914	Per cent. Mayari in mixture	Tonnage	Fuel Ratio	Yield	Tons of Flue Dust	Average, 24 Hours				
						Pounds Blast Pressure	PIG IRON			
							Si.	S.	Cr.	Ni.
13	57.2	453	1.02	.58	92	15.75	1.05	.025	1.35	.73
14	56.4	404	1.12	.52	111	16.00	.97	.034	1.67	.96
15	61.2	434	1.01	.57	91	16.25	.90	.024	1.59	.97
16	62.4	410	1.06	.56	67	15.50	.91	.026	1.70	.96
17	62.4	423	1.07	.56	94	17.00	.93	.027	1.73	.95
18	61.0	448	1.01	.58	69	16.50	.71	.035	1.66	.89
19	62.0	397	1.08	.55	81	15.75	.88	.036	1.63	.89
Average	60.4	424	1.05	.56	86	16.50	.91	.029	1.62	.91

The nodules used for this short test were the same in size as those used on No. 1 Steelton furnace in a test made from April 1st to 17th, inclusive. They did not come up to the standard of 75 per cent. on the 10 mesh, falling as low as 57 per cent. on 10 mesh, consequently the flue dust produced was too high, averaging about 12 per cent. of the ore charged. With standard large nodules, it is expected to keep the flue dust down to 5 per cent. of the ore charged.



BURDEN AND YIELD



CONDITIONS OF BLAST

TEST RUNS ON HIGH PERCENTAGES OF MAYARI ORE, MARCH–MAY, 1914. No. 1 FURNACE, PENNSYLVANIA STEEL CO., STEELTON

Furnace Design.

With conditions relating to quality of coke and preparation of the ore in such an unsettled state and demanding the undivided attention of everyone concerned, there was but little opportunity to experiment with any radical departures in furnace lines. The furnaces used for experimental work were those called upon to turn out the regular grades of iron, so that with the limited facilities no changes could be made, even if desired, which would effect the furnace operations to a marked degree under any one of these varied conditions.

At Steelton, the furnaces, as at present lined, have given fairly good results on Mayari ores, at least, as good as could be expected in the face of other difficulties.

As to the question of bosh angles, No. 1 Furnace, Steelton, has 71°; No. 2 Furnace 76°; No. 3 Furnace 74°; and the latest lined No. 4 Furnace 77°. With coke and ore troubles fast improving, we are inclined to favor the larger hearth, steeper and shorter bosh for Mayari ore practice, yet it is doubtful if the 80° bosh furnace will work well on these more refractory ores. However, time and experience will, no doubt, demonstrate the best practice. Up to the present, it can be stated as a fact that practically no difference can be noted between the working of Mayari ore on a 74° bosh furnace as against that on a 76° bosh; therefore, I see no reason why even a steeper bosh should not work well.

MODERN AMERICAN BLAST FURNACE PRACTICE

Edgar S. Cook

President, Warwick Iron and Steel Company, Pottstown, Pa.

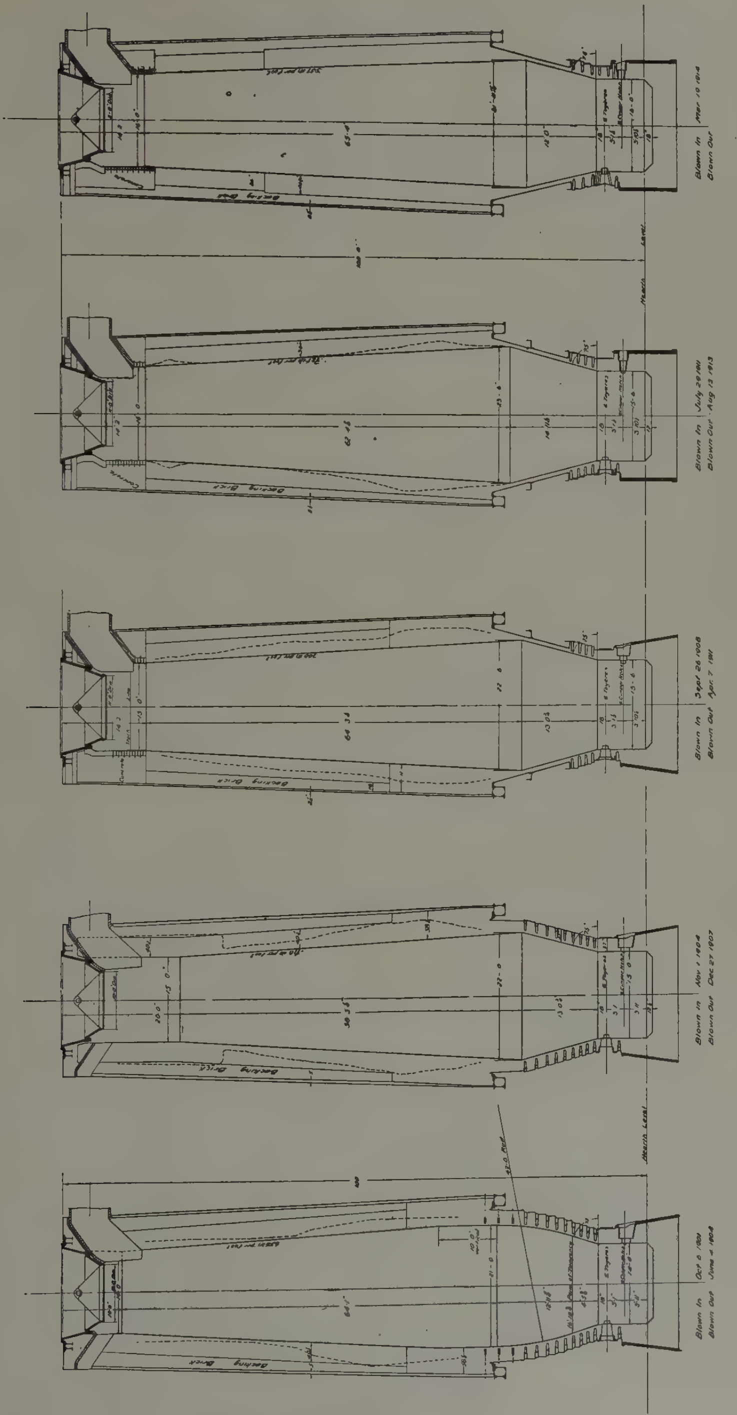
It is impractical, in the time allotted, to discuss many of the points brought out by Mr. Brassert in his interesting and comprehensive paper. I will therefore confine myself to the development of the lines of the modern blast furnace of the East, taking Warwick No. 2 as an illustration, and giving the records and brief information of the materials used and the furnace practice.

Lines and Records—Warwick No. 2.

The Chart on the opposite page shows the lines of No. 2 Furnace. The records of the work of this furnace are given in the Tables appended to this paper.

First Blast, 1901 to 1904. The lines of the first blast were obtained by practically making an enlarged photograph of the No. 1 furnace 70 feet high, which had done satisfactory work on merchant pig iron of various grades, using the usual materials commonly employed in the East. The records show that the first blast was extremely unsatisfactory. Passing through the period of organization on a new plant would account for some of the trouble, but the management felt that there were serious difficulties with the furnace itself.

Second Blast, 1904 to 1907. The lines of the second blast were copied from the Edgar Thomson standard at that time. It will be noticed that they are somewhat between the lines of "E" and "K" furnaces at Edgar Thomson, as shown in Mr. Brassert's paper. The decision to make this change was made after investigating the lines of most of the furnaces in this country which were doing good work. It was also decided—following this investigation—to eliminate all cooling plates above the top of the bosh. The work


Backing Brick
Hearth Level
Blown In
Blown Out

on these lines was fairly satisfactory, as is shown by the records. The Gayley Dry Blast was applied at the end of this blast and the results published the following year.

Third Blast, 1908 to 1911. The hearth was increased in diameter and the bosh jacket was installed; also a revolving top was used and protection at the stockline. The only reason for blowing out this furnace was the failure of the hearth jacket. The wear lines were extremely uniform and the furnace inwall was in good condition when blown out. This was the most satisfactory blast.

Fourth Blast. In order to use the bosh and bosh jacket, this furnace was blown in with the same size hearth. In order to save time and brick and try an experiment, the bosh was made nearly 2 feet higher than in the previous blast. This furnace gave more trouble with sticking and high pressure from the start, and did not work satisfactorily for so long a period. The effect was as if the furnace was partly worn out when it was blown in.

Fifth Blast. The hearth was increased to 16 feet and the bosh angle made 76 degrees. The bosh is 12 feet high, nearly 3 feet lower than in the preceding blast. This lining has only been in operation for a few months and the furnace is doing excellent work.

A paper could be written about each one of these blasts concerning the troubles that were experienced and overcome, or that could not be overcome until the next blast.

The consistency of the work is particularly noticeable, on account of the various materials used.

On the other furnaces successful attempts were made to use larger hearths, somewhat steeper boshes, and with the bosh jacket so designed that no offset or step could form in the furnace. One furnace was built with a bosh only 9 feet high and gave good results.

Experiments were made on a smaller furnace as to the dimension from the center of the tuyeres to the beginning of the bosh slope. These experiments seemingly confirmed the German practice that there is an advantage in having this dimension large on foundry iron, and an advantage in

having it as near nothing as possible on very low silicon iron. For the average merchant furnace about 18 inches is apparently satisfactory.

Materials.

Ore. All kinds of iron-making material are available in the East—Lake Superior ores, magnetic ores of various kinds, Clinton ore and foreign ores from Spain, Sweden, Greece, Africa, Cuba, and mill products, cinder, scale and pyrites cinder. All of these materials were used in varying proportions at various times on the No. 2 furnace.

Titaniferous ores were not available. Mayari, and a Greek ore of similar analysis, were used up to 25 per cent. of the mixture.

The problem of making up a blast-furnace mixture, in order to make the most money, is an intricate one. Careful observation and experience showed that there were certain general rules which were carefully followed in making standard iron:

First: To maintain a base of at least one-third first-class hematite ore.

Second: Not to use iron-bearing materials of inferior quality or hard to reduce, except at a large differential in price, and then only in small proportions.

Third: Magnetic ores well prepared can be used up to 40 per cent. of the mixture without seriously affecting the fuel consumption and tonnage, although these ores increase the cares of the blast furnace manager and make it much more important to carefully watch the operations and maintain uniformity, particularly in the distribution of stock and air.

Fourth: Select ores to maintain the slag volume at the desired amount for the particular furnace on a particular grade of iron, and to also keep the slag uniform in that ratio of silica to alumina, which experience has shown to be the best.

Preparation of Magnetic Ores.

The successful use of magnetic ore depends largely upon its preparation.

First of all the ore should be so small as to be readily attacked by the gases. Crystaline ores can be crushed to pass a ¼-inch ring and only a trifling percentage will pass an 80-mesh sieve. This ore works well, making little flue dust. The difficulty encountered in its use is a tendency to run ahead like sand; this can be partly overcome by the filling. It should be kept out of the mixture while blowing in and increased in the mixture by small percentages.

Very fine magnetic ore should be mixed with flue dust and sintered, the resulting product being satisfactory. If used without sintering, the flue dust made is excessive and there is a decided tendency to build on the bosh of the furnace.

Both magnetic separation and cobbing are practiced to remove silica and phosphorus. Where sulphur occurs the ores are roasted, or sintered or nodulized and the sulphur eliminated or changed to a less objectionable form.

Some magnetic ores reduce quite readily in the furnace, and these do not require such careful preparation.

In recent years, much progress has been made in ore preparation with resulting benefit to the furnace practice. Not only are the ores more readily reduced on account of this preparation, but they are much more uniform and lower in silica.

Fuel. The fuels available are hard coal, West Virginia and Mountain cokes, Latrobe and Connellsville cokes. The best Connellsville and Latrobe cokes were found to be the cheapest fuel except under special market conditions. A great deal of attention was paid to obtaining a uniform coke of the best quality. Provisions were made in the laboratory to analyze each car of coke when necessary. Each car was carefully inspected to make sure that the coke was of proper physical quality to resist the destructive action of the gases in the furnace. Much attention was also paid to careful screening of the coke at the furnace, all coke under ¾-inch being screened out—this again being screened through a ½-inch revolving screen and separated from the breeze, the resulting size being used in a small regular percentage in the furnace when it could not be sold or utilized for any

other purpose. If the fuel mixture contains a large percentage of this small coke, sticking and other irregularities result in a short time.

The fuel records are based on railroad weights with no wastage deducted.

Flux. Pure calcite and dolomite stone are available, the latter being much the cheaper in cost per ton. All calcite or all dolomite was used at times according to the alumina content of the slag. There are some excellent records on dolomite stone with a slag carrying over 3 per cent. of sulphur for long periods. It was of course necessary to this condition that the slag should be bi-basic and the alumina low to prevent the formation of spinel. There is much less danger of lime scaffolds in the use of dolomite than in the use of calcite stone.

It was found desirable to keep the slags practically uniform in the relation of silica to alumina for various grades of iron, and the proportion of calcite to dolomite is therefore maintained practically constant, the rule being to use ¾ calcite and ¼ dolomite on basic iron, and on foundry iron ½ calcite and ½ dolomite.

The percentage of stone used varied at times from 18 to 45 per cent. of the ore mixture. The best work was done on 18 to 20 per cent. of stone on basic iron, and about 24 per cent. of stone on foundry iron.

It was found desirable to keep the stone uniform in size, and clean. The smaller sized stone is best for basic iron, as it seems to facilitate the use of a more acid slag.

Practice.

The furnaces have always been carefully dried out before blowing in. The blow-in, such as used at Edgar Thomson, and described by Mr. Gayley in 1890, has always been the practice at Warwick, exceptional care being taken to see that small tuyeres are used in the blow-in, and that the tuyere velocity is kept as constant as possible as the wind is increased; also, that the wind and the heats are kept down until a heavy burden is at work so as to insure a low zone

of fusion. Care is taken in the first two weeks of the blast to coat the furnace with graphite in order to protect the brickwork.

As previously stated, fine magnetic ore is not used in the blowing-in mixture, but is added slowly.

Eastern practice varies so much with the special material conditions at many plants that little can be said of it in a general way.

In the past when acid slags were used on light burdens much trouble was experienced with high melted scaffolds. Later a change to very basic slags overcame the scaffold difficulty. The difficulty experienced with this practice was building on the bosh, and the fuels were high. Still later experience showed that with the use of better fuels and heavy burdens of well-prepared ore the heat can be kept in the hearth on a more acid slag. With this practice the fuels are lower and the building on the bosh is slower. However, the heat must be kept in the hearth, and if this cannot be done with burden it must be done with lime, whatever the consequences.

Sulphur is the usual limiting feature in acid practice.

For this reason all materials containing sulphur were avoided by us and an attempt made to run the furnace on a small slag volume and as acid as consistent with the making of good iron.

The troubles are high pressure and sticking, and the peeling off of the bosh with consequent overburdening, and closing of the tuyeres with iron.

Magnetic ores, particularly the finer ores, greatly increase the risks of furnace operation. The bosh jacket is preferred because as the bricks melt away the bosh plates can hold between them so much unreduced magnetic ore. A sudden cooling of the furnace due to water leaks or other causes, an error in distribution, dirty coke, and even suddenly cutting the heats too low, causes the carbon coating and accumulation of finely divided ore to come off the bosh. The consequent overburdening of an already heavily burdened furnace sometimes causes chilling.

For this reason great uniformity is required. The re-

volving top is practically essential. The relation of the bells to each other and the stockline, and the movement of the bells, is of great importance. The air distribution must be correct and the tuyere area very carefully fitted to the furnace and the practice. The length of tuyere is varied according to the quality of the iron and the condition of the furnace.

High uniform heats are essential to produce low fuel, as much of the magnetic ore must be reduced by the direct process of incandescent carbon.

The dry air plant is of great benefit, not only for the fuel saved but also because it eliminates the very expensive troubles which furnaces using magnetic ores experience during periods of high and irregular moisture. I feel that the dry air plant will be as well understood within a few years as hot blast stoves—that it is of great value under certain conditions, and a desirable luxury under other conditions. While many furnaces do not work well with high blast temperatures, our experience has been that with the dry-air blast we have been able to utilize the full power of our stoves, and this has been confirmed by Mr. Reese with the use of dry air at the furnaces in Cardiff, Wales.

The new lines and appliances have greatly decreased the difficulties. It is possible that steeper boshes, such as used at South Works, will be a further help. So far, however, we have been unable to build a furnace which will keep itself clean, and settle regularly, month in and month out. The records show that the work is good, but this is due to the prompt measures taken by a trained organization on the first sign of trouble.

Every irregularity is immediately given attention and an endeavor made to ascertain the cause. Small cleaning blanks are used or the furnace is run very acid for short periods. Large blanks or other excessive measures are used in case of emergency, as when the furnace starts to scour, with consequent cooling of the hearth and with the top of the furnace becoming hot.

Successful practice is closely allied to the construction. The ideal toward which we all strive is to so improve and

adjust our lines, construction, appliances and materials that the practice will be uniform and easy and consequently economical.

At first it was thought that the large furnace was only suited to the manufacture of basic iron. In the third blast foundry iron was made, 500 tons a day of high silicon on the lowest coke consumption known at the time.

After this low phosphorus iron was successfully made.

My remarks in regard to practice refer chiefly to basic iron. Foundry iron is made with less risk, although if low fuel consumption is expected the principles are the same. The margin of safety is greater on the foundry grades. A furnace that will do good work on foundry is often an absolute failure on basic iron, while the good basic furnace is usually an excellent maker of foundry grades.

Mr. Brassert's remarks in regard to organization cannot be too strongly emphasized. I feel that whatever success I have met with has been in a large part due to being able to interest the men, down to the keeper and cinder man, and, in the old days, the top filler. Often these men have given advance information, and have called attention to small details of operation which have proven of the greatest value in anticipating and correcting large troubles. Just as every detail of the operation should be studied, so should every man about the furnace plant be given attention, to the end that his eyes and brain may be utilized to secure smooth running.

Conclusion.

In summing up, the main points of interest are:

First: The Edgar Thomson furnace, which did the best work about 1900, using Lake Superior ores and making steel works iron, proved the most satisfactory furnace at that time for using the various ores of the East on merchant grades of iron.

Second: The development in the East has been along the lines of larger hearths and lower boshes, the same as the development in the West. Somewhat steeper boshes seem desirable.

Third: The large furnace, which at first was thought only suitable for making basic iron, has since been found to make all the grades of merchant iron—foundry, Bessemer, malleable, and low phosphorus—of a satisfactory quality, and with as low fuel consumption as the small furnace.

Fourth: Various difficult materials can be used up to a certain percentage, good work and long life be gotten out of a furnace, provided care is taken to see that the stock distribution and the air distribution are correct, and attention given to proper uniformity of operation.

It is hardly likely, as Mr. Brassert says, that there will be the development in the future that I have witnessed in the forty years that I have been actively engaged in the blast furnace practice. I feel, however, that new problems will be coming up from time to time, which will require the vigorous efforts of our best men to satisfactorily solve.

Moreover, it is sometimes hard to hold the advantage won. The older men pass on and, with the younger men lacking practical experience, errors creep in which are difficult to locate. Every mechanical genius cannot be expected to have the advantage of a blast furnace training.

The metallurgist must be always on guard to see that the mechanical engineer in improving construction does not interfere with the process.

There are no mysteries about a furnace, but there are many seeming mysteries which are usually a combination of a number of small errors, in construction, materials, fluxing, and management. These must be patiently sought out and eliminated one by one. Diagnosis is as difficult at times as the physician experiences in treating the human body.

YEARLY RECORD OF No. 2 FURNACE.

Year	Annual Tonnage	Daily Average	Pounds Fuel per Ton	Best Monthly Tonnage	Daily Average for the Month	Pounds Fuel per Ton	Annual Average Stone per Ton	Per Cent. of Burden of:				Top Heats	Stove Heats	Yield of Ore
								Hard Hematite	Soft Hematite	Magnetite	Mill Products			
1902	115519	265	2810	10595	353	2815	1424	35	33	16	16	803	1043	53.0
1903	134019	381	2791	12620	407	2695	1300	30	30	20	20	673	1147	53.2
1904*	84735	420	2608	13147	424	2482	1159	34	28	25	13	668	1040	54.4
1905	163155	454	2359	14796	477	2296	1097	41	28	24	7	475	1036	53.1
1906	165548	474	2237	16509	550	2190	1069	42	32	18	8	378	984	53.8
1907*	156643	450	2378	15522	517	2320	1074	34	28	29	9	375	1066	56.0
1908*	48248	492	2094	16976	547	2035	962	46	20	23	11	395	1062	51.1
1909	189778	526	2067	17831	575	1962	887	42	18	35	5	386	1157	53.3
1910	179435	510	2089	17797	574	1947	848	40	30	27	3	377	1092	53.6
1911	122250	481	2149	15940	514	2106	885	40	20	30	10	379	1121	53.6
1912	183416	507	2050	16491	532	2000	931	52	15	28	5	373	1147	54.7
1913*	76775	468	2306	14975	499	2154	994	40	13	42	5	515	1075	53.7

* In blast 30 weeks in 1904.
* Furnace blown out, December 27, 1907.
* Furnace blown in, September 24, 1908. (Dry Air Plant installed.)
* Furnace blown out, August 13, 1913.

No. 2 FURNACE.
COMPARISON OF BASIC AND FOUNDRY PRACTICE.

Kind of Iron	Analysis			Mixture				Average Daily Tonnage	Fuel per Ton R.R. Weight	Limestone per Ton	Stove Heats	Top Heats	Yield of Ore
	Sil.	Phos.	Sul.	Soft Hematite	Hard Hematite	Magnetite	Mill Product						
Basic	.49	.769	.040	19.6	47.6	27.8	5.0	575	1962	916	1157	386	53.8
Foundry	1.80	.787	.034	23.5	38.0	31.4	7.1	483	2236	803	1180	528	53.3

RECORD OF BLASTS OF No. 2 FURNACE.

Period	Total Tonnage	Daily Average	Average Fuel per Ton	Average Stone per Ton	Ore Mixture				Yield of Ore
					Hard Hematite	Soft Hematite	Magnetite	Mill Product, etc.	
1st. Blast	328251	360	2730	1294	33	30	21	16	53.5
2nd. Blast	507631	456	2325	1080	39	29	23	9	54.3
3rd. Blast*	464434	512	2097	878	43	23	28	6	53.0
4th. Blast	362963	491	2191	963	44	16	33	7	54.0

* Dry Air plant installed.

THE IMPORTANCE OF THE INVESTMENT FACTOR IN SALES POLICY

Thomas J. Bray

President, Republic Iron and Steel Company, Youngstown, Ohio.

I believe that upon consideration it will be agreed by men of experience in the rolling mill and steel industries that the "relative prices" of steel products are at the present time the lowest recorded in the history of the trade. By "relative prices" of steel products is meant, of course, their present selling prices as compared with wages and the prices of various commodities. In other words, the number of hours of labor, the number of bushels of wheat, or tons of coal, that a ton of steel will now buy is less than at any former period.

During the periods of extremely low prices of 1893–1894, and 1895–1898, which old time steel men always recall when discussing hard times and low profits, the selling price of a gross ton of steel billets would buy, roughly speaking, about 140 hours of unskilled labor, while now it will buy little more than 100 hours. The selling price of a net ton of merchant bars would then buy about 170 hours of unskilled labor, while now it will buy about 115 hours. Expressed in terms of mechanical labor, or mining labor, or in coal, or in terms of great commodities like wheat and corn, or in terms of taxes paid per ton of steel produced by steel companies, the same condition holds good, that the relative prices of steel products in this country are now lower than ever before.

This low selling price of steel products not only brings pressure on operating heads to reduce costs, but also necessitates, on account of the narrow margin of profit, extreme care in making sales.

It is obvious that under these conditions the fact that tonnage can be taken at the current market price is not a sufficient guide for taking or refusing it, but regard must first be had to the cost of producing the material. The sales manager, or head of the company, or whoever has the

last word in deciding day by day the prices to be put on products, or the length of time for which contracts shall be made, should have constantly before him complete cost data.

What Factors Constitute Cost.

For the use of the sales executive the total cost should be made up not only of the cost of material, labor, stores, scrap loss and other items necessary for operating comparison and control, but in addition there should also be included such items as the normal depreciation per ton of finished product, salaries, and general expense per ton of finished product, and other items which in an operator's cost sheet need not be allocated against the product. In short, the total costs of various products given to the sales executive, to be of use, should be so complete that if tonnage sufficient to give a full operation were sold at those costs the company would be able to pay all charges exclusive of interest on investment.

The importance of the subject of complete costs is my only excuse for the reiteration of matters which no doubt are well taken care of by the accountants of the various steel companies represented here.

In addition to the items just considered, and which I presume are covered in different ways by accountants in furnishing cost data against which sales are made, the sales manager, and other officers having to do with selling, should also, in considering sales at a narrow margin of profit, take into account the interest on investment per ton of each kind of product manufactured and sold. This was a matter of little importance when the total investment required was small and when the different steps in the process of manufacture from ore to finished steel were undertaken by separate companies and a profit was necessarily taken on each step. But with the integration of properties and processes there is a natural tendency to consider only one profit from ore to finished material; and it is obvious that unless this single profit is sufficient to give a fair return on the total investment the result will be, to say the least, disappointing.

To those of us who have had experience in the construc-

tion of steel plants, rolling mills, and so on, during the past twenty years, one of the most impressive features has been the progressive increase from year to year in the cost of construction, which of course has meant a corresponding increase in the amount of money invested. Not only has the influence of higher wages and generally higher equipment costs made itself felt in higher construction costs, so that the plant built in the early nineties, or even ten years ago, could not be duplicated today for its original cost, but changes in processes, in raw materials, and a variety of other causes have had their effect in increasing the investment factor.

Construction Costs Then and Now.

The typical American steel plant of the decade ending in 1900 may be said to have been an acid Bessemer works, which on account of the then low price for fuel, could be operated economically with a very cheaply built power plant. This fact, together with the simplicity of the process itself. meant a low investment per ton of product produced. Due largely to the decreasing supply of low phosphorus ore, the typical American steel plant is now a basic open hearth works. The investment per ton of ingots necessary to carry on the process from pig iron to ingots in a converter plant is about one-fifth of the investment per ton for the corresponding step in an open hearth steel works, so that the effect of the change of process on the investment factor is easily seen. It is true that it is sometimes maintained that, inasmuch as the ordinary open hearth plant uses only say 60 per cent. to 70 per cent. of a ton of pig iron per ton of ingots, this lessened need for blast furnace capacity (pig iron being replaced by purchased scrap) might be considered as an offset to the higher investment in the open hearth plant. But in my judgment this factor cannot be considered an offset, as the supply and price of scrap are at least as uncertain at the present time as was the ability to buy for extended delivery cheap Bessemer pig iron in the earlier years. The fact that in some cases the Duplex Process with its high pig iron consumption has been used, partly because of the uncertain scrap supply and its uncertain price, bears out this thought.

Factors Increasing Costs of Construction.

Furthermore, leaner ore has its effect on blast furnace tonnage, so that in general, the production of pig iron per cubic foot of blast furnace capacity is being lessened from this cause year by year, although this tendency may not be felt by those having ample supplies of rich ore.

With the increasing cost of fuel have come large increases in investment in the power plants of blast furnaces and steel works. Higher priced fuel has justified fuel economy, and the use of stokers, super-heaters, compound engines, condensers, low pressure turbines, gas engines, and electric mill drives. These improvements while necessary to combat an increasing fuel cost do not of themselves necessarily increase tonnage, and have a tendency to increase the investment factor per ton of steel produced.

Among other causes which might be mentioned tending to increase this factor has been the "Safety First" movement, improved sanitation, better housing conditions, etc., all commendable and necessary, but all tending to a higher investment per ton of steel produced.

It is also a fact that the large investments in plants have brought with them and made advisable the investment of money in large reserves of ore and coal, and the equipment that goes with them. Common prudence has dictated that the large investment in modern plants should be backed up by a reserve of raw materials. This was not so necessary in the early days of the steel business, when the plant investment was small and the limits of bodies of desirable ore and coking coal, within reasonable transportation distances from steel producing centers, were not so well defined. Leaner ore has also meant investment in concentrating and washing plants, and as the proportion of ore mined from shafts increases as against that from open pits, larger investments may become necessary because of this fact.

Some Factors Helping to Reduce Construction Costs.

It is true, that the ingenuity and organizing ability of the steel maker, engineer and operator have been able to

counteract to some extent this increase in investment. Through the growth of individual steel companies, or the combination of small companies to form large ones, a degree of specialization of operations on finished product in various lines is now possible which was impossible under former conditions. With larger tonnages under the control of single organizations, rollings come in sufficient quantity of one size to warrant, to a greater degree than formerly, the installation of special large tonnage mills. This fact together with the elimination of the former arbitrary limitation of output by labor on certain products have been the special causes which have served to offset in a degree the growth of the investment factor.

I believe I have given enough reasons for the consideration of the investment factor by the sales executive, especially in low priced times, like the present. An easy way to handle this question for sales purposes is to work out an investment factor per ton of capacity per year for each product sold, taking into account not only the money invested per ton produced, in real estate, plants, etc., but also the approximate amount of working capital required per ton produced per year for each product sold.

Some Construction Cost Items Considered.

Without attempting to give close figures, which of course, differ widely with different conditions, but simply for illustrative purposes, let us consider a modern steel company of moderate size, producing, say, 400,000 net tons of open hearth steel merchant bars and plates per year. Such a concern, if built up under present construction conditions, will probably, if provided with coking coal reserves for twenty-five years, have an investment in houses, coal shafts, mining equipment, coal reserves, and by-product coke ovens, of from \$7.00 to \$10.00 per net ton of capacity of finished steel per year. In blast furnaces its investment will be from \$8.00 to \$10.00 per ton per year of finished steel. Its open hearth plant, blooming mill, and billet mill will entail an investment of from \$13.00 to \$15.00 per ton per year of finished steel. Its bar mills and plate mills will require an

investment of $7.00 to $8.00 per ton per year of finished steel; while the working capital required will probably be from $10.00 to $12.00 per ton per year of finished product. I hesitate even to guess at the investment in real estate required per ton of finished steel, but it can easily run $1.00 to $2.00 per ton per year of finished product produced; while the consideration of the value of ore in the ground—depending as it does upon so many factors, like quality, cost of mining, and transportation—would take a separate paper and for brevity is omitted. If part of the steel produced by the open hearth plant, instead of going into bars or plates, goes into more highly finished products—like pipe, wire, sheets, tinplate, shafting, spikes, or into fabricated structural work—the investment factor per ton per year for those products will be increased commensurate with the character of the product; or if part of the product is sold in the shape of billets, or sheet bar, the factor will be decreased for those products. In any case, the accountant can work out the investment factor per ton per year for each product along the lines indicated, taking into account the working capital required as well as the fixed investment.

While the figures given above are intended merely to be illustrative, they are based on experience, and in the example cited, would show that without ore or transportation interests an investment factor of from $46.00 to $57.00 per ton per year is indicated. This would mean, taking the average of the two figures, ($51.50), that to make 6 per cent. on the actual money invested a profit above full and complete costs is needed of somewhat more than $3.00 per ton on each ton of steel sold. Of course, if the interest on investment on money tied up in ore operations and properties per ton of steel produced were added this amount would be still higher.

Conclusion.

I have tried to bring out briefly the importance of the investment factor in sales policy; but I realize that the stress of competition, the attempt to stimulate business by low prices, and the effort to keep operating may at times prevent its consideration. This may be necessary in choosing the

lesser of the two evils—that is, of closing down the works, or completely neglecting profits. But I believe that, even in hard times, the constant consideration of this factor together with true costs will at least tend to make the comparative prices of different steel products more in keeping with their relative cost and with the investment necessary to produce the products.

The statement made at the beginning of this paper concerning the relative prices of steel and rates of wages shows that the public has, on the whole, been well served by the steel industry, and that with higher wages, higher taxes, etc., steel prices have not been increased in proportion.

There is also a duty to stockholders, and if constant consideration of the investment factor may not prevent ruinous prices for spot business, it is hoped that its consideration in sales policy will tend to minimize the extension of these prices over long periods.

THE IMPORTANCE OF THE INVESTMENT FACTOR IN SALES POLICY

C. Snelling Robinson

Second Vice-President, Youngstown Sheet and Tube Company
Youngstown, Ohio.

Mr. Bray's paper is a real message, and in it he has advanced ideas of vital importance to those interested in the manufacture and marketing of iron and steel products.

The prominent points brought out are:

That the present prices of steel products as measured by purchasing power are less than ever before;

That the plant cost per ton of steel produced is greater than ever before;

That the "Investment Factor" is often not given the consideration that it deserves as an element of cost;

That there should be a close relationship between sales policy and costs.

Increased Return to Labor.

The low selling prices of steel products have been effectively measured by their values in labor, wheat and other commodities, and a careful examination of the statements made presents to us the fact that the proportion of costs due to wages has increased nearly 50 per cent. since the low periods mentioned by Mr. Bray. As labor constitutes the largest single item in the cost of any steel product—authorities placing it in some instances as high as 90 per cent. of the total—it is evident that the values of steel products have been largely effected by the liberal reward labor has received.

Returns to Capital.

Admitting that plant cost per ton of steel produced is more now than ever before, due largely to the cost of improved and labor-saving machinery and to changes in methods and processes, and recognizing that labor itself has

been generously requited—how has capital fared? The average return covering the last fifteen years has been satisfactory—and represents a reasonable profit. The earnings, however, for the last six months or more have not only been inadequate, but reflect a condition under which only the most modern plants, carefully financed and economically managed, could continue to exist, provided due regard were given to proper maintenance and depreciation charges.

The steel companies, as a rule, are managed by men above the average in sagacity and business ability, but it would appear that through the integration of properties the responsible heads of large companies may have become less mindful of profits on the separate progressive steps of manufacture than they were formerly when a profit on pig iron, on ingots, on blooms and on sheet bars was essential. The apparent tendency is to consider only a final profit on the article sold, and as a result in times of financial stress or business strife the "Investment Factor" may become obscured or entirely lost sight of. As an example, when this factor is properly considered the so-termed independent sheet mills are at present buying bars from producers at less than cost.

Sales Policy.

Mr. Bray makes a strong plea for a close relationship between sales policy and costs, and gives cogent reasons why the "Investment Factor" should always receive careful consideration in making sales.

If some steel companies do relate their sales to costs, it is obvious from certain recent prices, that all do not, or that at times many purposely neglect them. In other words, the policy of meeting the market is now much in evidence; a policy liable to be based on ruthless competition, and as ordinarily applied utterly disregardful of knowledge or consideration of costs. By it prices are simply met, many of them being phantasmal or those quoted by irresponsible or financially weak bidders; such a policy tends to inefficient effort on the part of sales managers and to trade demoralization.

On the other hand, a policy which gives due considera-

tion to costs tends to greater efficiency and to better trade conditions. Even those who hold that cost has little or no bearing on selling price must acknowledge that the psychological effect of knowing that a certain price must be obtained to avoid loss is in itself a marked stimulus to effort for greater returns.

Information for Sales Managers.

Recently the necessity for extras and their maintenance was ably discussed before this Institute. To assist in holding prices at a profitable level the sales manager, or whoever is responsible for sales policy, must be conversant with costs. To that end monthly statements should be available showing in their relation to each other complete costs, sales expense, the "Investment Factor" (made up of, say, 6 per cent. on working capital and investment in plant and 5 per cent. for depreciation) as well as the net prices obtained. The costs should be so sub-divided that they are adequate for intelligent guidance. The "Investment Factor" should vary in proportion to the normal tonnage on different sizes and kinds of product made in the same mill in a given time. The prices received for individual articles should be less cash discount and claim allowance, as the granting of unjust claims can be made a virtual price reduction. This information—no matter how imperfect may be the sales lists, standard discounts or differentials—would make clear what is the most desirable and profitable business, and should bring those who have been in the habit of selling by meeting the market regardless of whether the articles sold are more or less highly finished, to a realizing sense that the "Investment Factor" should not be lost sight of. It would show that in order to cover this item where billets and sheet bars might call for \$2.00 to \$3.00 per ton sheets and wire products would probably call for from \$4.00 to \$5.00 per ton.

Extent of Operations.

Without doubt one of the most difficult problems confronting the heads of our large companies is the question

of how to operate their plants during periods of depression such as we are now passing through.

At times of inactive buying, with diminished production and low prices, a way of decreasing cost, at least to the extent of the increased efficiency of labor, is open to all; and if at such times each would be content with a proper percentage of the business offered and seek to make other cost reductions, it is believed that in the long run a larger return would be made on the investment.

Taking orders at such times in the endeavor to run full and thereby lower cost, or with the hope of stimulating the market, or perhaps of causing weaker concerns to retire from the field, ofttimes proves to be inexpedient. Specifications do not always come out, and the older and less extensively equipped plants can well give smaller consideration to the question of the "Investment Factor" than many of the more modern ones. Their owners also at times disregard everything but manufacturing costs, cutting their labor (which is a much larger percentage of their cost) to the lowest point and continue to run. Therefore large companies, or the new ones which without proper regard to costs try to secure enough when orders are scarce to enable them to operate in full, must eventually find that they have injured themselves, and possibly more than their competitors.

Let us, then, be satisfied with our just proportion when trade requirements are not normal, and not neglect overhead charges beyond what a corresponding curtailment of output would temporarily warrant.

Conclusion.

Finally, in considering the problems which enter into the iron and steel business, we should have in mind that success is pre-eminently the goal all are striving for, and that in the last analysis the man responsible for it will be held strictly accountable by his stockholders.

If success is to be attained it must be through the most careful attention to operating costs, backed up by a sane selling policy—a policy that considers all points of cost and that appreciates the fact that the invasion of another's

legitimate territory must bring retaliation and harmful results.

There is such a policy; it can be pursued; and it is enlightened, being based as it is on an intimate knowledge of costs and market conditions and on co-operation and justice. By no other policy can prices be obtained that will subserve the true interest of labor, of capital and of the public.

THE INFLUENCE OF THE INVESTMENT FACTOR ON SELLING POLICY

Harry D. Westfall

Vice-President and General Manager of Sales, La Belle Iron Works, Steubenville, Ohio.

When invited to discuss this subject I thought of many things that have happened during the last few years, all having an influence on costs; but Mr. Bray has covered the ground so thoroughly that he has not only captured my first inspiration but has gone so much deeper into the subject that I consider myself fortunate to be able to second the motion.

A very complete statement has been submitted of new and proper factors in cost distribution; but the subject, if we are generous in our interpretation, has many angles, and the time seems opportune to make at least delicate reference to certain other features of its every-day application. It has doubtless been the experience of many, if not all of us, that we have regarded with some alarm the steady and probably permanent increases in producing costs; and I have found at times that a sober, second consideration of what we do, has frequently helped in making up our minds as to what we should do.

We all maintain elaborate accounting departments and regard them perhaps as the most necessary unit in our organizations. But, is it not a fact that we too often view such important data in the light of comparisons with the previous month, or with other years, rather than to be impressed with the vital influence it should exercise in the preparation of our price schedules? I venture to assert that we are not getting our full money's worth out of our actual costs, and I also contend that if a cost system is to mean anything it must be permitted to exert a controlling influence on prices. I believe this for the reason that the difference between a sales policy

based on cost and a sales policy based on something else is the difference between a sure profit and a hoped-for profit. There is no doubt that the man who is given the power to say the final Yes or No about selling should have (and always may have) a good working knowledge of the results of modern cost accounting; but it is my impression that we do not seriously consider costs except in case of last resort, or when competition becomes so severe that we know it would be wrong to go further. Then, it is, that we look around for some argument to fortify our courage in saying "No." In defense of this statement I submit that certain articles are today selling for less money than back in the nineties, and Mr. Bray has clearly proven that the cost of manufacture is several dollars per ton higher.

Do not gain the impression that I think costs are ignored, for they are not. All of us have spent many interesting and beneficial hours analyzing cost sheets; but when it comes to making prices, the easiest way is to make them upon what we think trade conditions are. When the demand is normal, or above, we endeavor to secure all the commodity will bring, and when conditions are reversed we force ourselves to be content with what we think competition requires. Neither is exactly right, for in each case values become to a certain extent speculative, either too high to stimulate continued consumption, or too low to encourage confidence. Both also suggest interference, for the former prevents a healthy growth of the industry and the latter is unfair to the capital invested.

If we keep moving in the same direction as in the past, it is only a matter of time when unusual profits during any period will be questioned; and if we are not permitted to anticipate a reversal in demand by creating reserves that will carry us through the famine, our better judgment will surely force the adoption of total cost *plus*, for a selling price.

Now, then, what are we going to do about it? In our personal relations we adjust our living expenses so as to harmonize with our incomes, and I ask if we do not owe it to ourselves and to our employers to adopt similar methods in conducting the business affairs entrusted to our care?

Mr. Bray concludes that under normal operating conditions an average profit of $3.00 per ton on the raw steel produced is necessary in order to guarantee 6 per cent. on the investment, with the proviso, however, that this does not include interest on the investment that has been made by most of us for the next generation. I would add that neither does it provide for irregularity of output due to the business public making up its mind periodically to cease buying.

It is not my mission to attempt to define a sales policy that would be proof against losses, for competition will always play an important part, and those of us who are anxious for success will meet the situation. But there is always a right way, and I maintain that what is fair and reasonable is above criticism. So why not base your selling prices, in good times or bad, upon mill costs, plus overhead, and then plus a reasonable rate of profit? If this plan were generally followed, I predict that actual selling prices would not, in any locality, vary more than they do now, and it would serve the purpose of removing certain kinds of demoralization which is about the most difficult thing we have to contend with.

To carry this phase a step further, we have frequently thought in connection with our own business that it would be feasible to establish a dead line, well within the limits of safety, at a point, say, that would relieve us from the charge of dissipating our reserves of ore and coal that cannot be replaced. We have reasoned that it has never been proven unfair or unjust to preserve a return on the investment for next year if it cannot be had during this year; but with a let-up in demand comes a terrible desire to run, and this coupled with competition as we find it, plays havoc with all such good resolutions.

There are other ways, perhaps more scientific, of arriving at a better method of making prices based on costs, and I can only suggest that we, as individuals, solve the problem in the manner best suited to our own industries. Sometimes I think that it would be well if the members of this Institute should indulge in dreams similar to those referred to infor-

mally at the Chicago meeting, and imagine their stockholders always in a happy frame of mind, secure in the belief that even if there was not enough business to go around, their holdings were not in temporary jeopardy. And then, after we wake up, handle our business in such a way that, regardless of output, we would insist upon a decent return upon the volume transacted.

My remarks may seem visionary to an extent and at variance with the fixed law of supply and demand, but each new year brings new ways and methods. We are no longer jealous of the prosperity of our competitors. There is more of a spirit of co-operation between buyer and seller than formerly existed. So why is it not fair to presume that, as we progress, a proper return on the capital invested in legitimate enterprise can be practically assured? This can be accomplished only when we arrive at the sane method of studying our costs first and making our prices afterwards.

THE PRACTICAL IMPORTANCE OF HEAT TREATMENTS IN THE STEEL WIRE INDUSTRY

John F. Tinsley

Superintendent, South Works, American Steel and Wire Company, Worcester, Mass.

The use, in the wire industry, of heat treatments in the broad definition of the term, is very old. In fact, the development of the wire business has been due primarily to an early appreciation and application of such fundamental heat treatment processes as annealing, hardening and tempering.

In the manufacture of wire, heat treatments take not merely an important position but an indispensable one, with a scope of application far broader perhaps than in any other branch of the steel industry. This is, of course, to be expected, not only because of the multiplicity of uses under the most exacting requirements of service to which the enormous tonnage of wire is put, and not only because of the extremely small individual parts manufactured from wire, but also because of the extraordinary amount of work required in reducing steel from the ingot, in which it is originally cast, to the comparatively small section of the finished wire. A better appreciation of the latter fact may be had when it is realized that a 2-ton ingot, when rolled and drawn into the average size telegraph wire, becomes elongated upwards of 20,000 times its original length.

The principal heat treatments used in the manufacture of wire, are: (1) annealing; (2) patenting; and (3) hardening and tempering. The object of this paper is to present as comprehensively as possible, consistent with the brevity that is necessary in the treatment of a very broad subject, a discussion of the practical application of these basic heat treatment processes, which affect by far the largest tonnages in the manufacture of steel wire.

THE FUNCTIONS OF ANNEALING.

In discussing heat treatments of steel wire, that of annealing naturally comes first, because it is the most common of all heat treatments applied to wire, being practically the only heat treatment to which the enormous tonnage of soft or low carbon steel wires is subjected, although the annealing of higher carbon wires for specific purposes, as will be outlined later in this discussion, is an important and growing field.

Annealing serves to accomplish three important functions: (1) To remove the effects of hardening due to cold work in wire drawing or cold rolling, thus making the steel ductile and soft. Annealing for this purpose covers principally the low carbon wires, i.e., with carbon .25 per cent. and under. (2) To refine grain—applied principally to the higher carbon rods and wires, i.e., with carbon .30 per cent. and over. (3) To obtain definite structure in the finished material—applied principally to the higher carbon wires, i.e., with carbon .30 per cent. and over.

Removing the Effects of Cold Work.

The first class of annealing to be described covers low carbon steel which, under the microscope, shows a structure consisting chiefly of a mass of grains of iron interspersed with dark patches. These dark patches contain practically all of the carbon of the steel in the form of iron carbide. The other ingredients of ordinary steels, such as manganese, sulphur, silicon and phosphorus, are not satisfactorily detected by the microscope; and, as they do not affect the structure of the steel appreciably, their effect may be neglected in this study of heat treatments, which is chiefly concerned with structure.

The structure presented by annealed steel depends principally upon the carbon content, and, as will be shown later when the heat treatment of the higher carbon steel wires is discussed, there is a marked difference in structure between the various carbons.

Fig. 1 shows a photomicrograph of a small section of a

specimen of an .08 per cent. carbon steel with a magnification of 100. The lighter grains occupying the greater portion of the area are iron, while the black areas contain the iron carbide (Fe_3C). As a matter of fact, these dark areas are made up of plates of extreme thinness of iron carbide alternating with similar thin plates of iron, and forming together a constituent characteristic of annealed steel, known to metallographists as "pearlite." This structure is apparent only with very high magnification and is shown more clearly in Fig. 7.

The Effect of Wire Drawing.

When a steel wire rod of the structure shown in Fig. 1 is subjected to the wire drawing process, a marked change in the grain structure takes place. With each successive draft, the grains stretch out in the direction of drafting until a point is reached when the grains have been elongated to the limit of their ductility. If subjected to further strain by further drafting they will part and the wire will break. Before this brittle condition is reached, therefore, it is necessary to heat treat the wire by subjecting it to what is known in the wire business as a "process annealing."

The effect of wire drawing in elongating the structural grain of the steel may be seen by comparing Figs. 1, 2 and 3. Fig. 1 shows the structure of the rod before drawing; Fig. 2 shows the structure after a 15 per cent. reduction from the rod; and Fig. 3, the structure after a 60 per cent. reduction from the rod. All of these photographs represent sections taken from a plane parallel to the axis of the rod or wire, not cross sections. The reason for the marked difference in grain shown in Figs. 1 and 3 may be grasped more clearly when it is appreciated that Fig. 3 represents a wire reduced in the wire drawing process to such a degree that it has become elongated 2⅓ times the original length of the rod.

The Effect of Process Annealing.

Process or "Works" annealing consists in heating the wire to a certain temperature, maintaining such temperature until the entire mass of steel is thoroughly heated

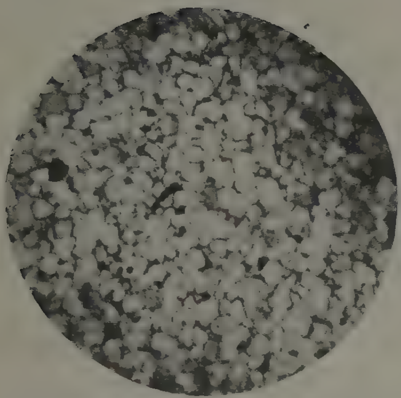


FIG. 1.—Steel, .08 carbon, annealed. × 100.

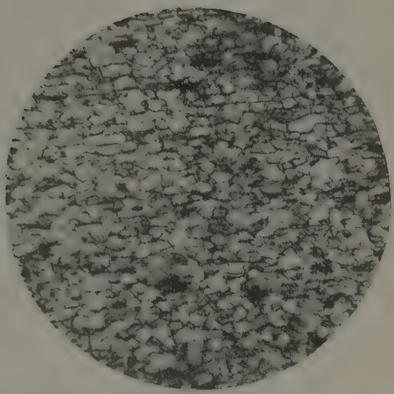


FIG. 2.—Steel wire, .08 carbon, given one draft, 15 per cent. reduction from rod. × 100.

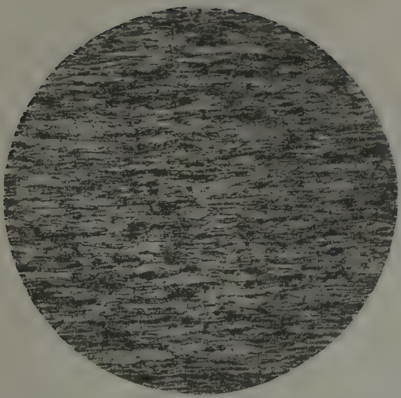


FIG. 3.—Steel wire, .08 carbon, given several drafts, 60 per cent. reduction from rod. × 100.

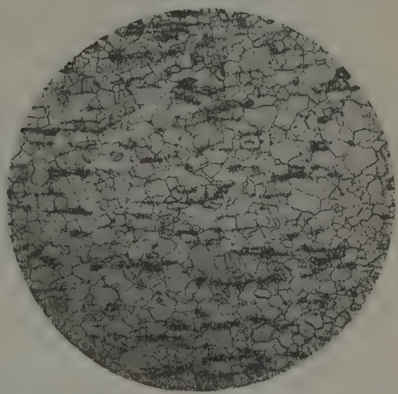


FIG. 4.—Steel wire, .08 carbon, hard drawn and then annealed below critical temperature. × 100.

through, and finally cooling down. Practically all prominent authorities on the metallurgy of steel state that the temperature of annealing must be above the critical temperature, which briefly defined is that range of temperature above which the iron and iron carbide are mutually in solid solution. Few of our authorities, however, seem to recognize the fact that in the most common of all annealing of steel wire—that to remove the effects of cold work such as drawing—it is not necessary to reach the critical temperature, which is 1300° F., or higher, depending on the carbon content. A temperature of 1100° F. is entirely sufficient to relieve the strained condition of the grain shown in Fig. 3.

Fig. 4 shows the same wire that is depicted in Fig. 3 after annealing at a temperature below the critical range.

In the annealing process the strained and elongated grains shown in Fig. 3, break up and rearrange themselves to form a new grain structure as shown in the photograph. The annealed steel of the structure shown is now in excellent condition to withstand further cold work in reducing it to finer sizes; or, if already at finished size, is in good condition to meet the demands of annealed wire service.

The effect of reduction of section incident to wire drawing on the tensile strength and ductility of steel wire, and the marked change brought about in these characteristics by annealing, as just outlined, is shown in Table A. This table is based on drafting and annealing practice in reducing a low carbon steel rod—in this case .10 per cent. carbon—to a fine size of wire. It will be noted that between 80 per cent. and 90 per cent. reduction from the rod or annealed wire can be taken before annealing is necessary.

In cold drawing from a soft rod or annealed wire, the heavier drafts can be taken when the material is in a relatively soft condition. The smaller the wire section the smaller the amount of reduction that can be taken, due to the reduced ductility of the wire and to its consequently lessened ability to withstand the heavy strains put upon the wire in pulling it down through the die. It should be understood of course that wire drawing practice is based also on other important conditions, such as speed of drawing and die lubricant, as

well as fundamental conditions relative to the size and uniformity of the rod, thoroughness of acid cleaning to remove the hard scale of ordinary hot rolled rods, and thoroughness of baking to remove the acid brittleness consequent to the cleaning process.

It is found in practice that in cold drawing from a soft rod or annealed wire, the increase in tensile strength is a direct function of the amount of cold work, almost independent of other conditions. Annealing practically brings the rod or wire, regardless of size, back to its original condition with regard to tensile strength and ductility. The increase of tensile strength and the effect of annealing as shown in the table, are illustrated more clearly in Chart I, from which it will be seen, that starting with a rod, there is

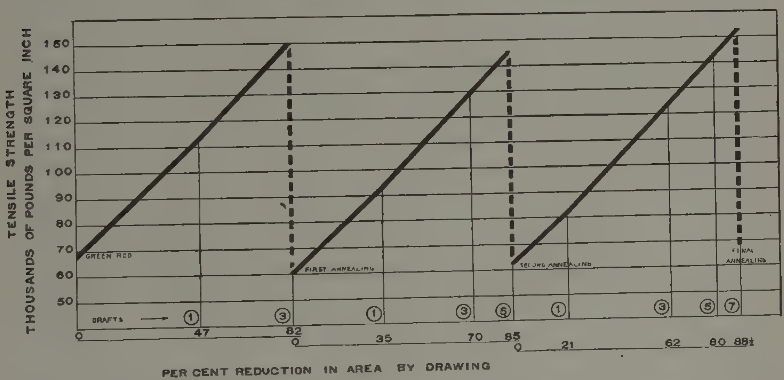


CHART I.—Showing increase of tensile strength due to drawing, and the effect of annealing, low-carbon (0.10 per cent.) steel.

a steady increase in tensile strength up to the annealing point, that the first process annealing reduces the strength of the wire practically to the original strength of the rod, and that the same relation holds in regard to any further drafting and annealing beyond this point. Of course, the results obtained on any two wires are not exactly alike but, if tests of a large number of samples were plotted, the line shown on the chart would represent good average practice. It will be noted that the final annealing does not bring the tensile strength as low as previous annealing. This is due simply to the fact that in annealing the fine sizes it is usual,

Condition of Material	Green Rod #5 Ga. .207"	First Draft	Third Draft	Process Annealed	First Draft	Third Draft	Fifth Draft	Process Annealed	First Draft	Third Draft	Fifth Draft	Seventh Draft	Annealed
Per cent reduction by drawing	0	47	82	0	35	70	85	0	21	62	80½	88½	0
Tensile strength pounds per sq. in.	68 000	113 000	150 000	60 000	93 000	130 000	145 000	62 500	82 000	124000	143 000	151 500	68 000
Per cent elongation in ten inches	25	2½	1½	30	3	2	1½	28	3½	2	1½	1	25

TABLE A.—Showing the effect of cold drawing and annealing on the physical properties of low carbon (0.10 per cent.) steel.

NOTE.—Dead soft annealing gave a tensile strength of 50,000 and an elongation of 32 per cent. both at the first and the second annealing.

Condition of Material	Green Rod #5 Ga. .207"	First Draft	Second Draft	Patented	First Draft	Third Draft	Fourth Draft	Patented	First Draft	Third Draft	Fourth Draft	Patented	First Draft	Third Draft
Per cent reduction by drawing	0	28½	51	0	30	50½	65	0	30	66	76	0	30	66
Tensile strength pounds per sq. in.	95000	122 000	146 000	115000	143 000	163000	176 000	128 000	156 000	190 000	208 000	156 000	184000	218000
Per cent elongation in ten inches	10.	2.9	2.8	8.2	2.8	2.7	2.6	7.8	2.0	1.9	1.8	6.0	2.0	1.9

TABLE B.—Showing the effect of cold drawing and patenting on the physical properties of higher carbon (0.50 per cent.) steel.

NOTE.—At the first patenting stage, process annealing gave a tensile strength of 70,000 and 18 per cent. elongation.

in order to avoid the mechanical sticking of the wire in coils, to anneal at slightly lower temperatures than in ordinary process annealing.

The Effect of Dead Soft Annealing.

In describing annealing to remove the effect of cold work incident to drawing, emphasis has been laid upon the fact that, to secure structure well suited to withstand further drawing, or in the case of finished wire to meet ordinary requirements for annealed wire, it is not necessary to employ temperatures above the critical range. However, the structure obtained in this manner is not quite the same as that obtained when the steel is annealed at temperatures above the critical range (1,300° F.) nor are the physical properties of the same wire subjected to these two different annealings exactly the same. In the latter form of annealing we would obtain what is termed in the wire mill a "dead soft" annealing, which is required for certain classes of finished wire subjected to very severe heading or upsetting operations.

The effect of "dead soft" annealing upon the physical properties of wire is shown below the process annealing column in Table A. The reason for this difference is that in heating above the critical temperature range the pre-existing structure is entirely obliterated, due to the iron and iron carbide going into solid solution and in cooling down forming a new structure. On the other hand, in annealing below the critical temperature the pre-existing structure is simply broken up and re-arranged but not entirely obliterated, and the deformation introduced by the cold work is thus not entirely removed.

In the annealing of low carbon steel wire, the rate of cooling from the annealing temperature is of little consequence as affecting structure, a fact which is much appreciated in the wire industry.

Refining the Grain by Annealing.

The second important function of annealing is that of refining grain, and its practical application in the wire mill

covers principally the medium and higher carbon steels. The structure of wire rods with regard to size of grain is dependent upon the temperature at which the rods are finished in the hot rolling mill and upon the rate of cooling through the critical temperature of the steel. In steel of low carbon this is not of as much importance as in the higher carbon steels, for the reason that the ordinary finishing temperature variations of good rolling mill practice have less effect on grain structure of soft rods, and therefore less effect on their physical properties. In higher carbon steels a fine grain is important, for it is this structure that makes for such steels their field of usefulness, where high strength, high elastic limit and great toughness are required.

Cause of Coarse Grained Structure.

Theoretically, the ideal structure would be obtained if the entire rod could be finished at about the critical temperature. But this is, of course, impracticable, for the reason that it is impossible to regulate the finishing temperatures so closely, and for the additional reason that there is, necessarily, particularly in rolling very long lengths of very small sections, a marked difference between the finishing temperatures of the first and last end of a rod. The higher the finishing temperatures above the critical range the coarser the grain, and the coarser the grain the more does the steel lack the qualities that give it value. In order to destroy the coarse or uneven structure that may be created as just described, it is necessary to anneal the steel by heating it just above its critical temperature and slowly cooling it down. Above this range the coarse crystalline structure which previously existed is entirely obliterated, due to the iron and iron carbide going into solid solution, in exactly the same manner as was described in connection with the dead soft annealing of low carbon wire.

The effect of overheating in coarsening the grain structure of a .45 per cent carbon steel and the refining influence of this type of annealing is shown in Figs. 5 and 6.

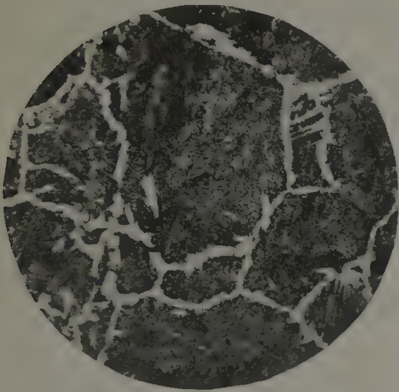


FIG. 5.—Steel, .45 carbon, overheated. × 100.

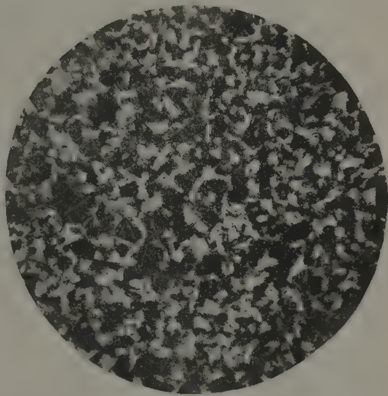


FIG. 6.—Steel, .45 carbon, annealed. × 100.

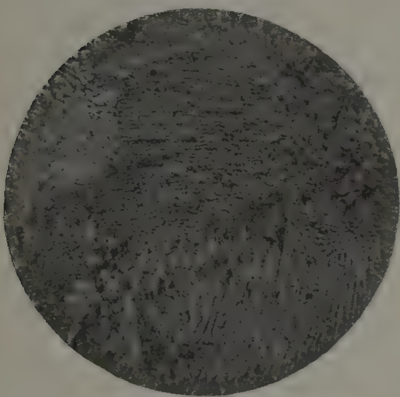


FIG. 7.—Steel, .85 carbon, annealed. × 1000.

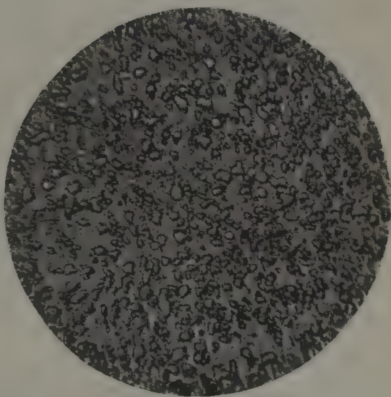


FIG. 8.—Steel, .85 carbon, annealed for globular structure. × 1000.

FIG. 9.—Steel, .85 carbon, patented. × 1000

Creating Definite Structure by Annealing.

The third and last class of annealing to be described—that to obtain definite structure—is one of comparatively recent development in the steel wire industry and one which promises to be of considerable value. It is now well known that the mechanical properties of a wire depend in great measure upon the structure of the material, and that it is beyond the scope of chemical analysis to reveal a knowledge of structure. The workability, so to speak, of a wire for certain purposes is primarily dependent upon a physical condition of the steel. It becomes apparent, therefore, that through the use of heat treatment scientifically applied and controlled there is opened a field of unusual opportunity. In this line very little could be done prior to the application of the microscope and pyrometer to the study of the practical problems of wire manufacture.

It cannot be said that the use of these instruments led to the discovery of anything new in the way of heat treatment processes; nor did they create new fields for the employment of wire. They do accomplish, however, two important things: (1) The making of a product of higher quality than had hitherto been the case, by supplying a material of superior structure for the purpose, and of greater uniformity than could possibly have been the case under less intelligent direction in manufacture; and (2) the placing of the manufacture of such materials in the wire mills on a scientifically improved basis, with fewer rejections and consequently with less cost to the user. Today a wire problem essentially involving structure is first studied under the microscope until the structure giving the best results is found. After that, by means of the pyrometer and other improved facilities of the present up-to-date wire mill, it is a simple matter to see that the heat treatment necessary to supply the desired structure is employed in the practical manufacture of the wire.

Annealing of the type under discussion is applied principally to the higher carbon wires. Since the structure of such wires can be varied considerably within a small

range of annealing temperatures, it covers specific products and not general classes, as would be the case in regard to the two previously described types of annealing.

Figures 7 and 8 illustrate excellently this special type of annealing. These photographs show the structures of two annealed pieces of the same coil of high carbon wire, in which the annealing temperature of the one specimen was 1300° F., and of the other 1250° F. It is impossible to identify the structure by a simple observation of the fracture, which is the ordinary rough and ready method; nor is it possible to regulate annealing temperatures so closely without the use of pyrometers.

THE PRACTICAL SCOPE OF PATENTING.

In passing to the next great class of heat treatment applied to steel wire, Patenting, it is interesting to note that we likewise pass to another class of wire as regards grading by carbon content. As has been previously pointed out, annealing covers primarily the lower carbon steel wires, with special and restricted application to the medium and higher carbon steels, while patenting naturally covers the medium carbon steels, being employed chiefly on carbons between .35 and .85 per cent. In low carbon wires, softness and ductility are the qualities desired both in order to facilitate the working of the metal, and, except in the case of hard drawn wires, in order to make the finished material of commercial and practical value. In the medium carbon steel wires, on the other hand, strength and toughness are required for both process and finished wire. Patenting makes possible this combination of strength and toughness, and to this process is due in large measure a broad field of application for steel wire.

Classes of Products Patented.

From a tonnage standpoint, wire rope is the most important product of this class of heat treatment. In some respects it is the most important from a quality view-point,

for the reason that in the manifold uses of wire rope the safety of human life is of vital consequence. There are also economical considerations relative to the handling of enormous tonnages at low cost, of which there is no better illustration than that furnished by the steel industry itself in the mining, loading and handling of tremendous quantities of ore and coal.

It should be appreciated, of course, that it is not within the power of patenting or any other heat treatment to make the proverbial "silk purse out of a sow's ear," for the best results in any steel product require the proper quality in the steel itself and proper treatment at every stage of its manufacture. However, in the manufacture of good rope wire it is possible through improper patenting to make the converse true, and produce a sow's ear from a silk purse. There is probably no feature of the wire business that has been given more scientific study than the heat treatment of rope wire. Rates and degrees of heating and cooling have been standardized to such an extent through the use of the microscope, pyrometers, and testing instruments, that a degree of uniform quality is reached that previously was impossible.

Another important class of wire dependent for its superior quality upon the patenting process is music wire for pianos and other stringed instruments. In order to have tone and hold pitch music wire must possess extremely high tensile strength and must also have suitable physical properties to enable it to be applied in the instrument. By a proper combination of drafting and patenting it is possible to obtain music wire from a .70 per cent. carbon steel which will have a tensile strength of 400,000 pounds per square inch, and be sufficiently tough to be wrapped about itself without breaking, and be swaged flat to one-half its original thickness without splitting. Through this remarkable combination of properties, which in steel are usually antagonistic, music wire may justly be said to represent the highest development in the manufacture of wire. Without the patenting process as we know it to-day, it would be impossible to produce wire of such characteristics.

The Structure of Patented Wire.

The high strength and toughness of patented wire are due to its carbon condition and to its peculiar structure. The first step in the patenting process is to heat the wire to a temperature above its critical range. As previously explained, when steel is heated above its critical temperature the iron and iron carbide go into a solid solution. This, of course, causes the carbide of iron to become homogeneously distributed. In patenting, the degree of heating is regulated according to the carbon content of the steel, the size of rod or wire, and the time the material is subjected to the heat. After sufficient heating, the next step is to cool the material rapidly below its critical range, the structure obtained depending upon the rate of cooling. In practice, patenting is usually conducted as a continuous operation, the wire being led through the heated tubes of a furnace and cooled by being brought into the air or into a bath of molten lead. comparatively cool but seldom under 700° F.

A better understanding of the structure of a patented wire may be had by a comparison of the structure obtained by slow and by rapid cooling. If the steel after being heated is allowed to cool slowly through the critical temperature range, the homogeneous pre-existing solid solution of iron and iron carbide separates into a heterogeneous mixture of two constituents, resulting in the plate-like structure called "pearlite," in which, as described previously, iron and iron carbide arrange themselves independently in alternate thin plates. In the patented wire structure, on the other hand, the cooling through the critical temperature range is too rapid to permit the separation of the iron and iron carbide into this plate-like structure. In a patented wire, part of the carbide of iron is in solid solution and the remainder, while not in solid solution, has not had time to form into plates. The difference in structure between slow and rapid cooling is seen in Figs. 7 and 9.

The photomicrograph of the patented wire shows, as a result of the rapid cooling, a structure that might be termed nondescript. Metallographists will recognize the structure

as "sorbite," which, in the cooling of the higher carbon steels from above the critical temperature, is that stage of transition just preceding the pearlitic, the final condition of annealed steel as shown in Fig. 7. The patented wire, therefore, represents an unsegregated condition as against the segregated or coarsely laminated structure of annealed wire. The high tensile strength of patented wire is due to the amount of carbon in solution, and its toughness to the fineness of the grain structure.

Functions of Patenting.

Patenting serves two important functions in the wire business: (1) In the process of manufacture, the removal of the effects of cold work, such as drawing. (2) In the finished wire, to give in conjunction with cold drawing, the required combination of strength and toughness.

The effect of wire drawing on medium and high carbon wires is similar to that previously described in connection with low carbon wires. The structural grains lengthen out in the wire drawing process, and patenting is resorted to as conditions demand to relieve the strain before the limit of ductility of the grain structure is exceeded. Strictly speaking, patenting is not necessary simply to relieve strain, for annealing would serve that purpose, but the structure obtained by patenting permits much further cold drawing than does the structure obtained by annealing. This is due primarily to the increased ductility and toughness of the patented wire. The effect of patenting as just described, is shown in Table B and Charts II. and III.

Table B represents typical practice in manufacturing a certain wire of .50 per cent. carbon steel from a No. 5 gauge (.207 in.) rod to a finished size of .02 in. The rod in question as it came from the rolling mill had a tensile strength of 95,000 lbs. per sq. in. and an elongation of 10 per cent. After the first draft of 28½ per cent., there is an increase in tensile strength of 27,000 lbs. per sq. in., and the elongation is reduced to 2.9 per cent. After the first patenting of the wire it has a tensile strength of 115,000 lbs. per sq. in. and an elongation of 8.2 per cent. It is then subjected to 4

drafts, being thereby reduced 65 per cent. from the first patenting point before the second patenting is necessary.

After the second patenting, the wire has a tensile strength of 128,000 lbs. It is then drafted 76 per cent. further before the final patenting, which leaves the wire with a tensile strength of 156,000 lbs. The properties of the finished wire depend largely upon this last patenting and the subsequent drawing to the finished size. In the case in question the wire was drawn 3 drafts and reduced 66 per cent. from the last patenting size, ending at finished size with a tensile strength of 218,000 lbs. It will be noted that the tensile strength of the wire immediately after patenting is higher as the size of wire decreases. This is due to the fact that in practice the smaller the wire the more quickly it cools, and consequently the greater the amount of carbon in solution. This, as explained previously, is the condition of a patented wire that makes for its strength.

In Table B and the note thereto are given the corresponding tensile strength and elongation of the same wire when patented and when annealed. It will be seen that the tensile strength of the annealed wire is 70,000 lbs. per sq. in. as against 115,000 lbs. per sq. in. of the patented wire. This is due to the fact that, on account of the comparatively slow cooling in annealing, none of the carbon of the steel is in solution. It might be supposed that, owing to its being softer and of higher elongation, the annealed steel would withstand a further degree of drafting than the patented steel. On the contrary, however, on account of the rapid loss of ductility characteristic of the annealed wire structure, the annealed structure will not withstand drawing to anywhere near the same degree as will the patented structure. Generally speaking, the patented wire structure has more than twice the ductility of the annealed.

Chart II. shows graphically the increase of tensile strength in cold drawing from a rod of .50 per cent. carbon steel, wire .02 in. in diameter and the effect of patenting in removing the results of the cold work. It indicates also the importance of the patenting process in creating a structure that permits an increase, by heavy drafting, of 50,000

lbs. per sq. in. in tensile strength, and leaves in the finished wire a remarkable degree of toughness rather than brittleness. Incidentally, it may be noted from this chart that

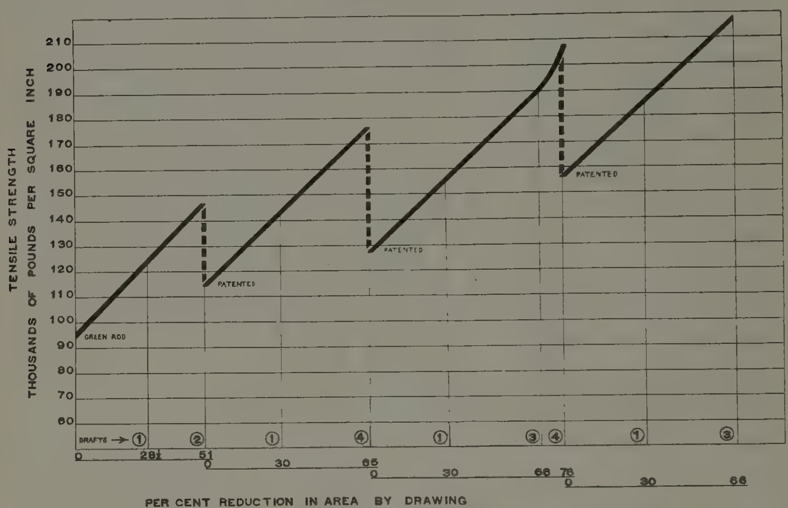


CHART II.—Showing the increase of tensile strength due to drawing, and the effect of patenting, medium carbon (0.50 per cent.) steel.

the same regular increase in tensile strength, due to drawing, is characteristic of the higher carbon steels as of the lower carbon steels previously shown.

Obtaining High Tensile Strength.

Chart III. shows a typical practice in obtaining a tensile strength of 375,000 lbs. per sq. in. in a music wire .03 in. diameter from a patented rod .192 in. in diameter, of .70 per cent. carbon. It indicates the marked increase in tensile strength from the last patenting point, and emphasizes the remarkable character of a wire of such strength possessing the workable properties necessary for music wire. It will be seen that from the last patenting point the wire is reduced about 94 per cent., i.e., elongated 18 times its length, and to do this on the wire in question, 19 drafts were taken. The increase in tensile strength per sq. in., due to this heavy drafting, amounts to about 200,000 lbs. from the last

patenting point. In the final drafts there is an enormous increase of tensile strength. In fact, as the curve shows, a certain reduction towards the end increases the tensile

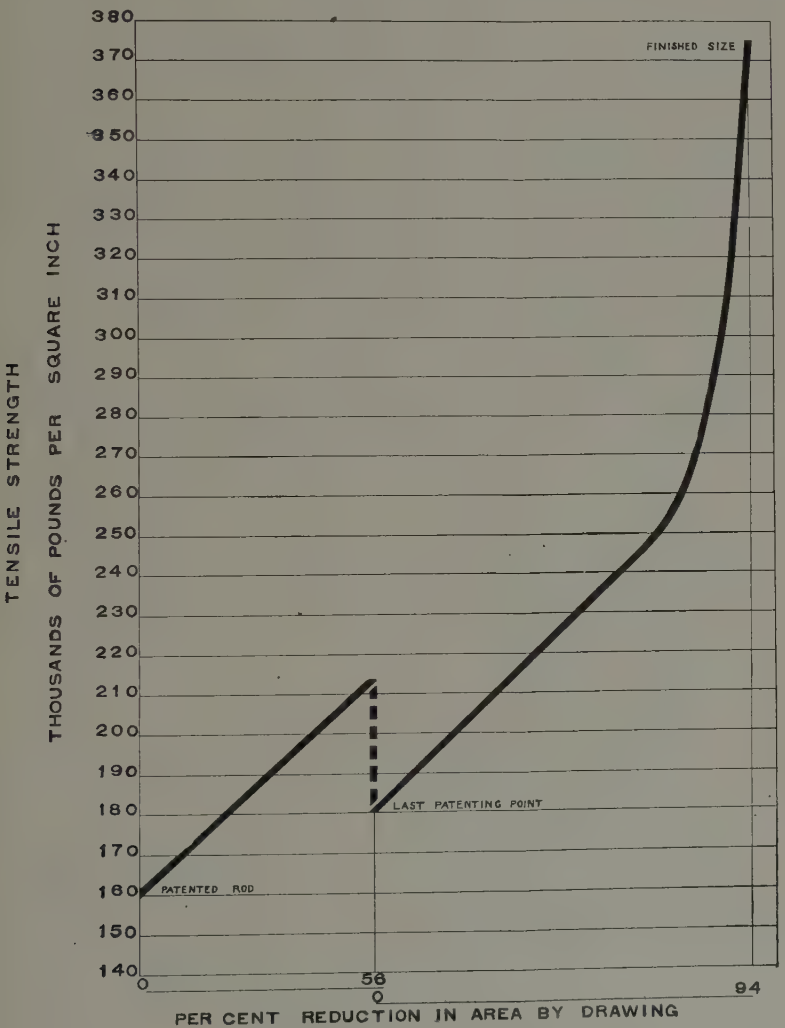


CHART III.—Showing the process for producing .03-inch wire (0.70 per cent. carbon) having a tensile strength of 375,000 lbs. per sq. in.

strength much more than an equal reduction near the patenting point. One might think a wire made according to the above practice would be as brittle as a clay pipe stem;

but, on the contrary, it is singularly tough, and stands wrapping, bending and flattening to a truly remarkable degree.

PRACTICAL SCOPE OF HARDENING AND TEMPERING.

We have now come to the third class of heat treatments applied to steel wire—hardening and tempering—processes which affect not only a large tonnage but an extensive variety of wire. The principal commercially important grades of wire dependent upon hardening and tempering are clock and watch spring, typewriter, motor and door check spring, umbrella, dress stay, knife blade, razor blade, measuring tape, band saw, hack saw and curtain spring wire, all of which are heat treated as wires. There is, moreover, still further a large field of use for wires which are hardened and tempered after being formed into springs, tools and miscellaneous special products.

Hardening and tempering is probably of broader commercial importance and application than any other type of heat treatment given to high carbon steels. In the past fifteen years it has been given tremendous impetus by the growth of the automobile business and the increased use of alloy steels. Furthermore, the commercial value of this class of heat treatment of steel has been appreciated and emphasized in recent years in practically all lines of manufacture and use of steel products.

Outside of the manufacture of wire, hardening and tempering are usually separate and distinct operations. But in wire the two terms always go together, there being practically no field of usefulness for wire simply hardened. It naturally follows, therefore, that in wire making, hardening and tempering should be conducted usually as a continuous process. In the making of tempered wire, the material is first run through the heated tubes of a furnace, then quenched quickly in a bath of oil or water, then run into the tempering bath of, say, molten lead, each wire being in continuous motion from the time it enters the heating furnace until it is

wound on a reel. Such wire products as springs made of untempered wire, hardened and tempered after forming, do not of course, have the several steps conducted as a continuous process, but there is no difference in essential principles.

In the development of the subject matter of this paper, for the purpose of associating readily the various classes of wire with the several heat treatments, annealing has been shown to cover primarily the low carbon steels, and patenting, the medium carbon steels. Hardening and tempering apply to the higher carbon steel wires—those in which the carbon range is from .65 per cent. to 1.00 per cent.

The Process of Hardening and Tempering.

In hardening wire the first step is identical with that previously described for patenting, and is accomplished in practically the same manner. That is, the wire is heated above the critical temperature to enable the iron and iron carbide constituents to go into solid solution before quenching. After quenching, the steel, on account of its sudden cooling through the critical temperature, is hard and brittle. Cooling in this manner is too rapid to permit the segregation of the constituents, iron and iron carbide; and, as a result, considerable of the carbon content is in solid solution, the amount depending upon the total carbon in the steel and the rate of cooling. In the discussion of patenting it was pointed out that carbon in solution causes hardness in the wire. It will be apparent that in hardening, as above defined, the amount of carbon held in solution will be much greater than in the patenting process, due to the much more rapid rate of cooling through the critical temperature, secured by the use of a quenching bath of low temperature. The structure thus obtained in the hardened wire depends on the rate of cooling. Small sections will be "martensite" —containing most of the iron carbide in solution; larger sections will be "troostite"—containing less iron carbide in solution; still larger sections will be "sorbite"—containing still less iron carbide in solution.

Besides martensite, troostite and sorbite, there are many intermediate "transition structures" formed by the different

cooling rates of sections of different sizes. The hardened material contains more iron carbide in solution than is desired in the finished hardened and tempered wire, that is, the hardened wire is harder than is desired. The hardness is finally lowered to the desired degree or "temper" by carefully adjusting the temperature of the "tempering" bath.

It will be apparent from the foregoing that hardening and tempering are of a contradictory nature as separate treatments, the hardening operation creating an excessive hardness which the tempering operation reduces to the proper degree, dependent upon the use to which the material is to be put.

This process of hardening and tempering, simple as it appears is, in practice, the most complicated in principle of any of the heat treatments described, and demands great accuracy of temperature control to secure the fine shades of temper demanded by the multiplicity of uses to which the finished product is applied by the consumer.

Functions of Hardening and Tempering.

Since the hardness and brittleness of wire simply hardened are such as to make it practically useless for commercial purposes, the effect of the tempering process is to remove some of the brittle hardness from the steel and to toughen it. The efficacy of tempering is due to the fact that hardened steel is apparently in an unstable condition and seems ready on slight provocation to return to a stable form. When hardened steel is subjected to even a low tempering heat, the carbide in solution tends to separate out. It follows that the higher the tempering heat the greater will be the amount of iron carbide released from solution, and the lower will be the hardness or "temper" of the finished product. At a tempering temperature of 1250° F. even a hardened .90 per cent. carbon wire will lose practically all its hardness and be virtually in an unhardened condition.

Temperatures Employed in Tempering.

In tempering wire for the greatest desired hardness, the temperature of the bath may be as low as 400° F. Tem-

pering heats between this and 1200° F. give practically any desired hardness. In passing it may be stated that the field of commercial tempered wire requirements is such as to necessitate a wide range of temperature on the various quenching baths in the tempering room of a wire mill.

In general, the reheating incident to tempering is usually considerably below the critical temperature.

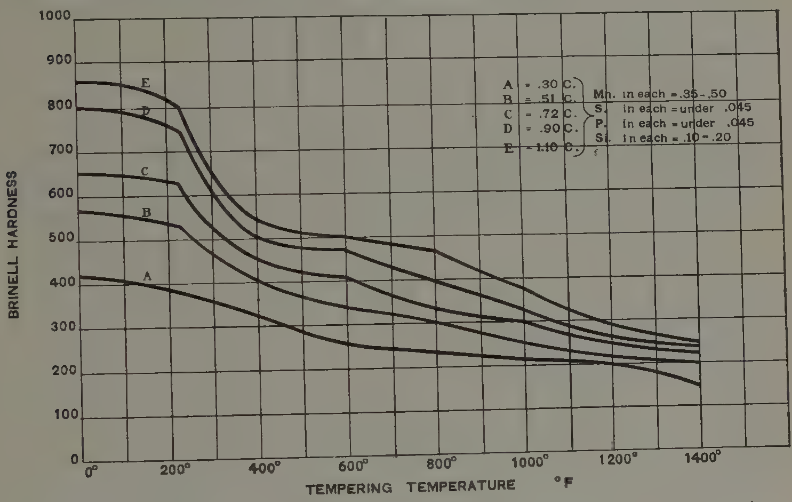


Chart IV.—Showing loss of hardness due to tempering steels of various carbon content.

Chart IV. shows the loss of hardness due to tempering carbon steel at varying temperatures. The horizontal distances represent the tempering temperature, and the vertical distances the hardness by the Brinell test. The plotted curves are based on actual tests of spring stock of practically the same analysis and grade of steel as regards manganese, sulphur, phosphorus and silicon, while the carbons vary from .30 per cent. to 1.10 per cent.

It will be noticed that there is a marked loss of hardness on all wires tested between the temperatures of 200° F. and 600° F., the most marked loss being between 200° F. and 400° F., and that the higher the carbon the greater the loss of hardness, especially at the lower temperatures. Furthermore, it will be seen that at 1300° F. the hardness of all the samples is practically the same, irrespective of carbon con-

tent. In fact, at this temperature even the highest carbon wire shown is relatively soft and ductile and may be drawn several drafts. Thus is it possible to obtain in any steel, within the limits imposed by its carbon content, any desired temper, whether it be extremely high or correspondingly low.

Of the various classes of hardened and tempered wires, razor blade represents the highest temper, band saw and corset wire the medium temper, and spring wire the relatively low temper.

Effect of Tempering on Tensile Strength.

Chart V. gives the tensile strength of a hardened .70 per cent. carbon wire at various tempering temperatures, from

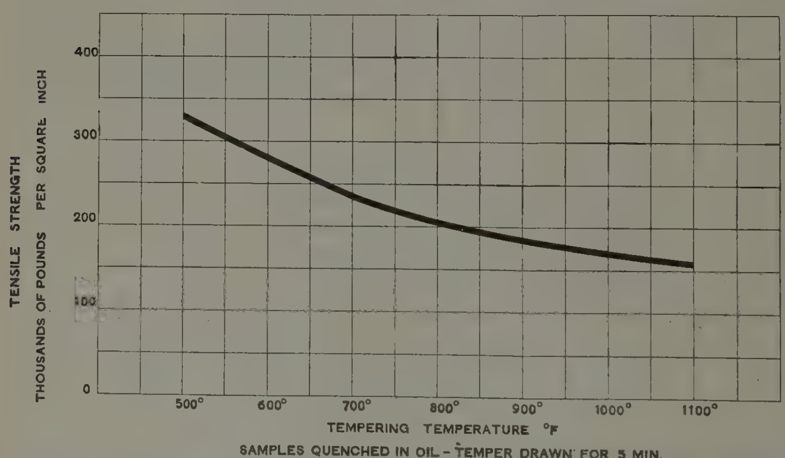


Chart V.—Showing the effect of the tempering temperature on the tensile strength of 0.70 per cent. carbon hardened wire (diameter .080 in.)

which the marked effect of tempering in affecting physical properties will be evident. With varying tempering temperatures between 500° F. and 1100° F., the tensile strength runs from about 340,000 lbs. per sq. in. to 150,000 lbs. per sq. in. At the lower temperature the decrease in tensile strength is, as we should expect, much greater per 100° F. range than at the higher temperatures. From 500° F. to 600° F. there is a drop of 60,000 lbs. per sq. in.; while be-

tween 1000° F. and 1100° F. the drop in tensile strength amounts to only about 10,000 lbs. per sq. in.

CONCLUSION.

From the foregoing discussion of the several heat treatments of importance in the wire business it will be apparent that at the basis of the industry there are certain fundamental laws which govern all processes in the manufacture of steel wire, whether it be cold treatment incident to drawing or heat treatment incident to the various operations described herein. Like all natural laws, those governing the behavior of steel in the manufacture of wire are inexorable, and the results obtained depend primarily upon the determination of those laws and upon their proper recognition and consideration in actual practice. Herein lies the reason for the vast difference between wire mill practice of the past and that of the present. The heat treatments which are applied to-day with such beneficial results were known then, but the underlying laws governing them were not. The scrap and rejections in the wire mill, the lack of uniformity and the unsuitable quality of the product, and the complaints of customers were all too frequently ascribed to the "devil in the steel." With the establishment in the past few years in our colleges of broader courses for the study of the nature and behavior of steel, and the resultant advent into the steel business of technically trained young men, and with the establishment of laboratories for the study of practical steel problems, with their invaluable aids in the shape of the microscope and the pyrometer, there has been given an impetus to a development in the steel wire business that has been unprecedented. The present day wire mill, with its hundreds of pyrometers and automatic temperature regulating and recording apparatus, gives silent but forceful testimony to the passing of the old type of "practical" man whom Professor Sauveur has described as "the industrial Philistine clumsily standing in the way of scientific applications to industrial operations."

In the works with which I am associated, a physical

laboratory for the study of heat treatments and other metallurgical problems connected with the manufacture of high grade wire was established several years ago. A convincing proof of its practical value lies in the fact that the facilities for carrying on this work have been steadily increased. To-day we have a large force of technically trained men in this laboratory, a costly and extensive equipment, and a separate building devoted entirely to the work.

Our physical laboratory is in every sense a practical and efficient adjunct to our producing department. Of fundamental importance in the practical application of the work of a laboratory of this kind, is the training of the men carrying on the work. To make their work of the greatest value, these men should be more than merely technically trained. We believe that the excellent results we have obtained in the heat treatment of wire are due in large measure to the fact that our laboratory men, in investigating a problem, study first all the conditions pertaining to the uses to which the product is to be put by the customer, and follow personally all investigations and experiments in the works' processes bearing on the subject.

In this way our laboratory men are made to recognize practical conditions, while our workmen become thoroughly trained as to the problem and the methods adopted for its solution. Thus, we have found it possible to overcome prejudice which the practical man often has for "theory," and to establish in its place a spirit of eagerness for better practice.

The results already obtained warrant us in feeling that there is ahead of us abundant opportunity for making steel of even greater value in the service of mankind.

THE PRACTICAL IMPORTANCE OF HEAT TREATMENTS IN THE STEEL WIRE INDUSTRY

JAMES W. SMITH

Factory Manager, The Wyman & Gordon Company, Worcester, Mass.

It is a pleasure to add a few words to the interesting and thoroughly practical paper presented by Mr. Tinsley.

From an intimate connection with the steel wire industry for a number of years, I fully recognize the importance of heat treatment to that industry, and the improvement both in output and in quality of products from mills where heat treatment has been given scientific and systematic study.

The products of the works with which I am now connected are drop forgings. In this work most exacting physical and chemical requirements are specified. To those handling steel products to meet rigid specifications, it is well known that heats of identical analysis and other results of examinations of the steel itself in regular common practice laboratory methods will not always produce the same physical qualities under the same heat-treating and working conditions. In addition to this, the various steels are so sensitive to heat treatment that to obtain the uniform high standard products required it has been found necessary in these works to establish the system of making a preliminary investigation and heat-treating standard for every heat of steel received and before any of the same is put into process of manufacture.

To accomplish this a thoroughly equipped chemical, physical and metallographical laboratory is maintained. The force employed in this laboratory, in addition to their investigation work, are constantly kept in intimate contact with the heating and heat-treating work at all stages of the forging process. Our experience has proven the practical application of such a laboratory in that manner to be of the first importance.

Formerly it was necessary to measure steel treating temperatures with very crude instruments, such, for example, as that of the determination of the proper temperature of a lead bath by the immersing of a dry pine stick in the bath for a certain number of seconds and establishing the temperature by the appearance of the charred portion of the stick.

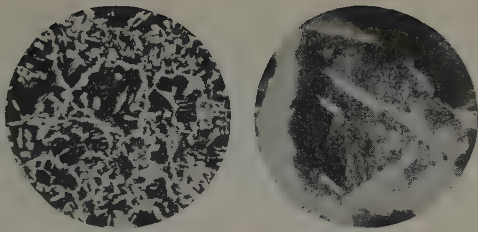
Proper heat treatment requires the use of accurate temperature-measuring instruments, and with the development of pyrometer manufacture in recent years accuracy along this line is now obtainable.

Assuming the use of an accurate temperature indicator, it is vital that the stock under treatment shall be at the temperature desired and as indicated by the pyrometer. Particular mention is made of this point because in many cases where careful heat treatment has been attempted and the desired result has not been obtained, temperature-measuring instruments have registered the temperature of the medium surrounding the stock, which is not necessarily the same as the temperature of the actual stock by a considerable amount.

The rapid change of structure and physical properties with the different temperatures within the usual heat-treating range of approximately 1300° to 1700° Fahrenheit for hardening and 800° to 1200° Fahrenheit for drawing, is shown on the microphotographs herewith. Each Figure (pages 157 and 159) is illustrated by two microphotographs, of which the first has a magnification of 100 and the second a magnification of 600.

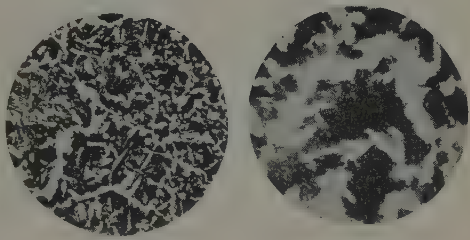
Fig. 1 shows the structure of the steel after being quenched at a temperature of 1300° F. and annealed at 1090° F. The structure is seen to be coarse and to consist entirely of pearlite (the darker constituent) and ferrite (the lighter constituent). The ferrite and pearlite are the two softest constituents which steel can have, and will be found in all forged or rolled and slowly cooled carbon steel. The critical range of this steel is about 1425° F. As we did not exceed 1300° F. on our quenching temperature, practically no change has taken place in the structure of this steel by

Fig. 1.



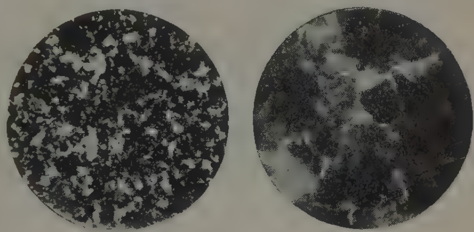
Hardened at........1300° F.
Drawn at. ....1090° F.
Elastic Limit.......38,750 lbs.
Ultimate Strength...82,750 lbs.
Elongation in 2 in...26.5%
Reduction of Area...43.0%

Fig. 2.



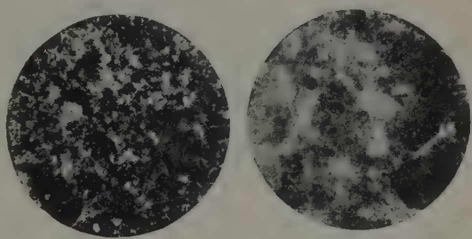
Hardened at........1400° F.
Drawn at..........1090° F.
Elastic Limit.......49,250 lbs.
Ultimate Strength..94,500 lbs.
Elongation in 2 in...19.5%
Reduction of Area...44.8%

Fig. 3.



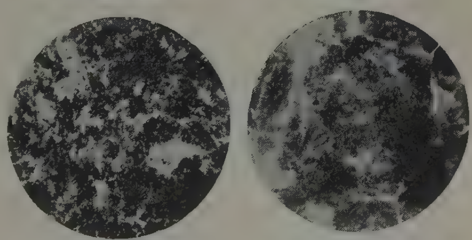
Hardened at........1520° F.
Drawn at..........1090° F.
Elastic Limit....... 77,500 lbs.
Ultimate Strength..107,250 lbs.
Elongation in 2 in...21.8%
Reduction of Area...58.8%

Fig. 4.



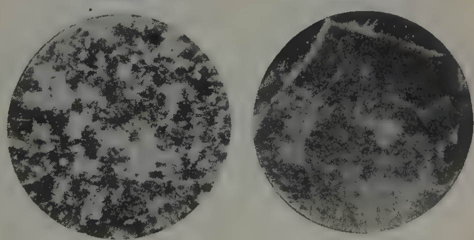
Hardened at........1600° F.
Drawn at..........1090° F.
Elastic Limit....... 75,000 lbs.
Ultimate Strength..111,250 lbs.
Elongation in 2 in...21.0%
Contraction of Area,53.7%

Fig. 5.



Hardened at........1725° F.
Drawn at..........1090° F.
Elastic Limit....... 80,500 lbs.
Ultimate Strength..119,500 lbs.
Elongation in 2 in...17.1%
Reduction of Area...45.4%

Fig. 6.



Hardened at........1800° F.
Drawn at..........1090° F.
Elastic Limit....... 86,750 lbs.
Ultimate Strength,.114,750 lbs.
Elongation in 2 in...17.1%
Reduction of Area...41.2%

this heat treatment from its properties when in a forged condition.

Fig. 2 shows the steel quenched from 1400° F. and annealed at 1090° F. We find some change has taken place. The dark constituent in the first set of pictures, the so-called pearlite, still remains dark in color, but it has now changed into a new constituent called "sorbite." That this new structure differs from the pearlite of the first set may easily be seen on comparing the higher power photographs, where it will be noticed that the laminated structure of the pearlite has entirely disappeared. The white constituent still remains the same, the free ferrite. The sorbite combines at the same time the greatest hardness and percentage of reduction of area of all the constituents of steel, and is the structure most sought for in parts that require a high elastic limit combined with a large reduction of area. In this case, we see that the temperature of quenching is high enough to harden up all the pearlite, but not high enough to make the excess ferrite dissolve in the sorbite. In other words, the piece was quenched when in the critical range of temperature and not when above it.

In Fig. 3, showing the steel quenched at 1520° F. and drawn to 1090° F., we find a marked change. Here the entire structure consists of sorbite, except for a very small amount of free ferrite, which is nearly always present in treated pieces of this cross-section. In this case the piece was heated above its critical range and everything driven into solution, forming the so-called solid solution. When quenched, this was retained mostly as martensite, and upon drawing this broke down into the sorbite, which is so much desired. We may consider Figs. 4 to 6 together. It will be noticed that the structure in all still remains sorbitic but the grain size is best shown in the higher magnifications, increasing very markedly as we increase the hardening temperature.

Figs. 7 to 12 show the steel hardened at the same but drawn at different temperatures. From Figs. 1 to 6, which we have just seen, it is observed that the grain size is governed by the quenching temperature, and since in Figs. 7

Fig. 7.

Hardened at........1550° F.
Drawn at.......... 900° F.
Elastic Limit....... 85,500 lbs.
Ultimate Strength..127,250 lbs.
Elongation in 2 in...18.7%
Reduction of Area...45.1%

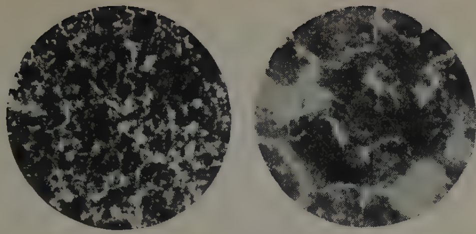


Fig. 8.

Hardened at........1550° F.
Drawn at..........1020° F.
Elastic Limit....... 80,500 lbs.
Ultimate Strength..115,500 lbs.
Elongation in 2 in...20.3%
Reduction of Area...51.9%

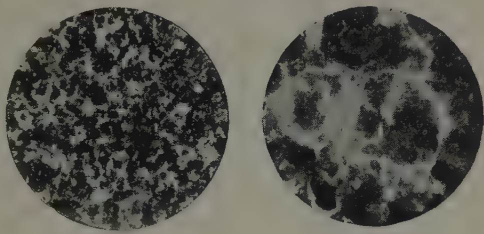


Fig. 9.

Hardened at........1550° F.
Drawn at..........1100° F.
Elastic Limit....... 75,250 lbs.
Ultimate Strength..114,000 lbs.
Elongation in 2 in...21.0%
Reduction of Area...52.2%

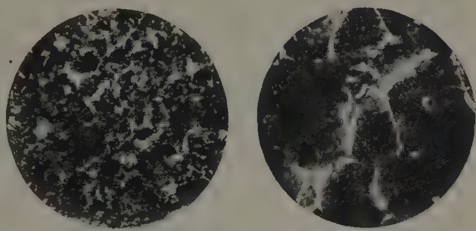


Fig. 10.

Hardened at........1550° F.
Drawn at..........1200° F.
Elastic Limit....... 69,500 lbs.
Ultimate Strength..104,250 lbs.
Elongation in 2 in...24.2%
Reduction of Area...58.5%

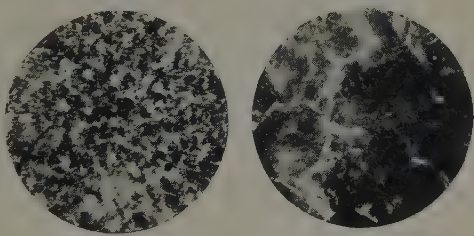


Fig. 11.

Hardened at........1550° F.
Drawn at..........1300° F.
Elastic Limit.......63,500 lbs.
Ultimate Strength..95,000 lbs.
Elongation in 2 in...28.6%
Reduction of Area...62.0%

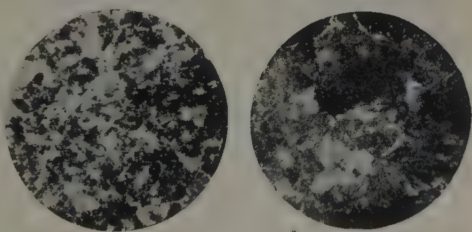
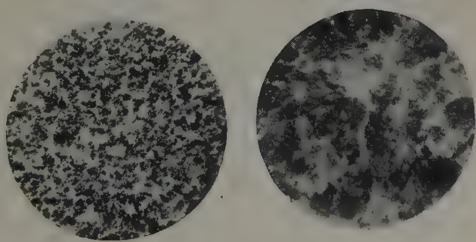


Fig. 12.

Hardened at........1550° F.
Drawn at..........1400° F.
Elastic Limit.......53,000 lbs.
Ultimate Strength..82,750 lbs.
Elongation in 2 in...23.4%
Reduction of Area...60.3%



to 12 the steel was all quenched from the same temperature, we should expect the grain size to be the same throughout. This is the case with the exception of the last one (Fig. 12), which was drawn at 1400° F. In this case, the drawing temperature was at the beginning of the critical range, and we see the sorbite breaking up to form finally the pearlite and free ferrite with which we started. In all other cases, we have a structure consisting mainly of sorbite, with small amounts of free ferrite.

In the next two diagrams (Figs. 13 and 14) are shown graphically the variation of ultimate strength, elastic limit and reduction of area, at the same temperatures shown by the microphotographs just previously referred to.

The widely varying physical properties shown by these charts with changes of 100° only in temperature emphasize the importance of the two points previously referred to, namely, the use of accurate temperature-indicating instruments and the certainty that the stock which is undergoing treatment is at the temperature desired and as registered.

By heat treating alone, forgings with an approximate cross sectional area of four square inches, for example, are in .50 carbon steel regularly given the following physical properties:

Tensile strength	112,000 lbs.
Elastic limit	77,000 lbs.
Reduction of area	52%
Elongation	17%

In nickel chrome alloy steel with carbon content .40, nickel 1.25, chrome, .70, the following physical properties are produced:

Tensile strength	135,000 lbs.
Elastic limit	116,000 lbs.
Reduction of area	53%
Elongation	17%

In both of these cases the steel is in a perfectly machinable condition.

VARIATION IN PHYSICAL PROPERTIES OF MEDIUM CARBON STEEL DRAWN AT 1090 °F AND HARDENED AT VARIOUS TEMPERATURES

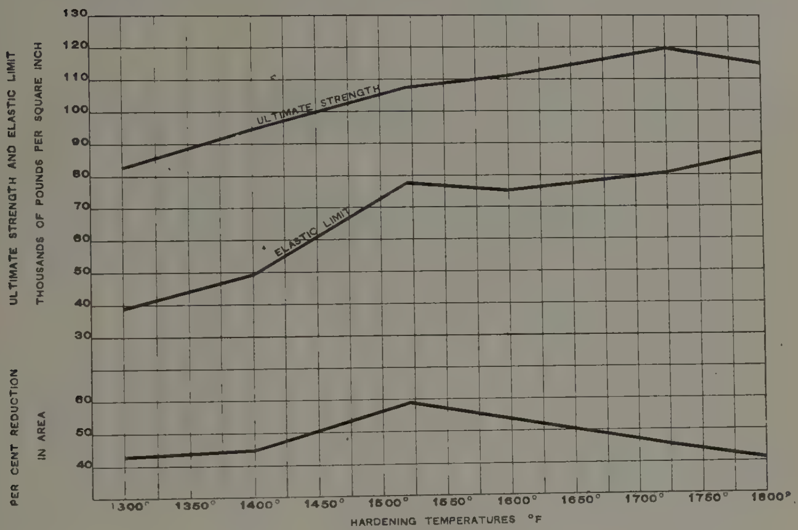


FIGURE 13

VARIATION IN PHYSICAL PROPERTIES OF MEDIUM CARBON STEEL HARDENED AT 1550 °F AND DRAWN AT VARIOUS TEMPERATURES

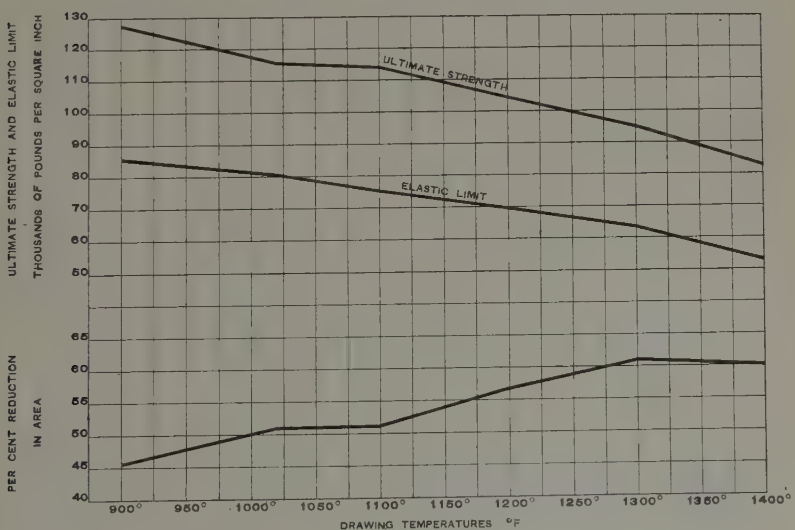


FIGURE 14

Depending upon the use to which a wire may be put, a simple carbon steel wire with carbon content .55 to .60 can be patented and drawn after patenting to a size having the following physical properties:

Tensile strength.......220,000 lbs.
Elastic limit..........121,000 or 55% ult. strength

This same wire of the same finished size and same physical properties as given can be double heat treated, that is, tempered and drawn to the following physical properties:

Tensile strength.......220,000 lbs.
Elastic limit..........189,200 or 86% ult. strength

These figures show an instance of widely different physical properties in two wires of the same size and identical analysis due to manipulation, that is, heat treatment as combined with cold drawing in the one case, and heat treatment alone in the other.

With the opportunity for the combination of heat treatment and subsequent cold working, rapid changes and advances must be made in wire structures, resulting in highly improved physical properties.

TRANSPORTATION

J. Fred Townsend

Traffic Manager, National Tube Company, Pittsburgh, Pa.

Transportation is a problem that we are all more or less familiar with, and I will not attempt to deal with its early forms, such as the conestoga wagon, canal, and river craft, but shall confine myself to the chief means of conducting transportation at the present time, the railroad.

American Railroad Development.

Let us consider for a moment the American railroad development. Rapid strides have been made during the last decade in rehabilitating the property generally—reduction of grades, eliminating the curves, reconstructing the roadbed, replacing bridges and structures with larger and stronger material, and laying heavier steel rails, to care for the motive power and rolling stock that has been doubled in capacity, building second and third tracks and making extraordinary improvements in terminal yard facilities.

About thirty-five years ago, the maximum freight carload was 24,000 pounds. The New York, Chicago & St. Louis Railroad was constructed at that time. It was built and equipped upon the most advanced ideas, which prompted some one to suggest its popular name, "Nickel Plate," and its new freight cars were all of 40,000 pounds capacity. This car would carry nearly double the load of the cars then generally in use.

All railroads throughout the country commenced enlarging their equipment, and during the next ten years the 50,000- and 60,000-pound-capacity cars appeared. To-day we have the 100,000- and the 140,000-pound-capacity cars, and it would be hard indeed to convince some people that the limit has not been reached.

However, when such a bulky commodity as coke can be loaded to the highest limit in the modern freight car, i.e., to 10 per cent. above marked capacity in the 100,000-pound cars, it would seem to a layman that the unit of

transportation should be increased, and instead of going through the slow and expensive changes of raising the limit 10,000 or 20,000 pounds at a time, a 200,000- or a 300,000-capacity car should be adopted.

Transportation is King.

Half a century ago there was a saying, "Cotton is King." Later we were taught that steel was "king" and that any fluctuation in the steel market was immediately reflected in other lines of business. Others claimed that grain was "king," and pointed with pride to the bumper crop years. Even to-day some are predicting a great revival in business as soon as the crops are harvested, on the theory that good crops and good times always travel together.

How long would any of these kings rule if it were not for the real king, Transportation, that makes it possible to assemble the raw materials at convenient points where blast furnaces, flour mills, or other manufacturing plants are located and the products of the earth are transformed into merchantable articles, to be again turned over to the transportation lines to be moved to the markets of the world?

Thirteen years ago, or shortly after the United States Steel Corporation was formed, President Schwab brought this question before the traffic managers in a very forceful manner by making the statement that there were three items of cost: First, the raw materials; second, labor; third and last, but not least, transportation.

Steel's Contribution to Improved Transportation.

What have the steel producers done to improve transportation during the period referred to? There can be no question but that the most remarkable progress has been made in the reconstruction of manufacturing plants, increasing production and decreasing cost of operation. In the tonnage of Pittsburgh alone in thirteen years this has resulted in an increase of 107,589,450 tons. This seems almost unbelievable, but the actual figures compiled for the railroad tonnage alone of the Pittsburgh District for 1900, was 57,005,465 tons, while for 1912, it was 164,594,915 tons,

an increase of 189 per cent. To handle this enormously increased tonnage, there has been a continual struggle to get sufficient cars to keep the mines and mills supplied.

During this period, the steel producers have doubled and trebled the size of ships on the lakes and increased the capacity of dock machinery for the more rapid and economical transportation of ore. And it seems to me the railroads' opportunity to increase their net revenue irrespective of increased wages and expenses is here, and that they can accomplish this by following the example of the iron and steel manufacturers in increasing their facilities and then making the best use of them. This can be accomplished by doubling the capacity of freight cars, making the limit 300,000 pounds per car with six wheel trucks. The gross weight of such cars loaded would not be as much as the new Mallet locomotives that are being very generally adopted.

Limit of Economies Through Larger Cars.

During the last twenty years, the maximum freight car capacity has increased only 100 per cent., while the locomotive capacity during the same period has increased 400 per cent. The wide difference between the increase in the capacity of the locomotives as compared with the carrying capacity of the freight cars has necessitated the very long freight trains in order to give the heavy locomotives an economical load. This has resulted in an enormous increase in the maintenance of the small freight cars.

The question will naturally be raised as to why the railroads do not adopt a very much more substantial car of 150 tons capacity. The answer can be found in the records of all railroads in this country, which show that during the last ten years over 60 per cent. of the increased capacity of the freight cars has been unused in practise, while the extra cost of hauling the greater dead weight and the extra cost of maintenance has been incurred.

The fact is that everybody is complaining. Engineering experts who study these questions, as well as the railroad executives and operating officers, are surprised and disap-

pointed because big engines and big cars have apparently failed to accomplish expected economies. Shippers whose business has been disturbed by periodical increases in minimum weight requirements are disposed to complain because the railroads disregard commercial conditions, which demand the small carload unit; while the railroad traffic managers, pressed on one side by their operating and executive officers to get bigger loads for the bigger cars, and on the other hand meeting the protest of the shippers against further increase in the minimum weight conditions of the tariffs, are discouraged and almost desperate.

The demand for a small carload unit would not enter into the shipment of such commodities as coal, coke, iron ore, grain, building material and other commodities which are sold and handled in large quantities, under conditions which would make the shipper indifferent as to whether they moved in carloads of 20 or 100 tons, assuming the cost of loading and unloading to be the same.

The attitude of the shippers toward the big carload does not depend entirely upon the capacity or the cost of loading or unloading, but rather upon the way in which it is bought and sold—whether sold by a man who has a large quantity to sell or bought by a man who wants a large or small quantity—the desire of the retail merchant to get the minimum carload of flour, because of the original investment, interest in insurance cost of carrying the stock, depreciation in quality, chance of falling market, and so on. The same thing is true of sugar, canned goods, beans, and everything in the list of goods handled by small jobbers or very large retailers. In fact, when you get outside of the limited list of very large jobbers, nearly every buyer wants the smallest quantity on which he can get the minimum delivered price. If the railroads expect such people to buy a large quantity and co-operate in the loading of cars to capacity, their freight tariffs must offer indemnity for the greater cost of handling such larger quantities; and to get complete co-operation on the part of shippers, the tariffs should offer some material inducement to trade in large quantities, thereby loading cars to capacity.

Should Not the "Wholesale" Principle Apply?

It would seem that any remedy must involve some practical application of the wholesale principle to the transportation business; and for the same reason that the price paid for most commodities is in inverse ratio to the amount purchased, the railroads should, within the limit of their maximum car capacity, give the lowest rate to the man who makes the largest shipment.

The freight tariffs of the European railways are based on the wholesale principle, all rates, generally speaking, being graduated according to the quantity shipped. The American railroads have made what seems to be the mistake of limiting their rates to two base units—the carload, which is anything more than 36,000 pounds or whatever may be the prescribed minimum weight, and the less-than-carload, which is anything under 36,000 pounds and within the limit of the money charge which would be made for the minimum carload shipment.

To have only the two units for rate-making, the carload lot and the less-than-carload lot, was not advisable even twenty-five years ago, when the minimum was 20,000 pounds and the carload rate was applied upon relatively small quantities. Under the present-day conditions, when the shipper is expected to furnish full loads for cars of 40 and 50 tons capacity and requested to load not less than 18 or 20 tons in order to get the carload rate, there is still less justification for the failure of the carriers to work out some graduated scale of rates, according to the weight of such consignments, or in some other way make freight tariffs which would permit the forwarding of any shipment, however large or small, at a rate which would bear some consistent relation to the cost of service.

Grain tariffs generally provide that the rates will apply only when cars are loaded to capacity. In other words, the minimum weight is the marked capacity of the car in case of corn, wheat, etc., while the minimum weight for oats or other bulky grain is based upon cubical capacity of cars used. Railroads are not building cars of capacity less than

80,000 pounds. Therefore a shipper could not get the car load rate, which we will say is 15 cents per 100 pounds, unless he forwarded 80,000 pounds, or is able to get a smaller car. But it is difficult to get cars of 60,000 or 70,000 pounds capacity and almost impossible to get cars of capacity less than 60,000 pounds.

Difficult to Arrange an Equitable Plan.

The question has been raised as to why the present method of rate-making is considered better than the European method, or if not better, why the European method is not to a greater or less extent observed in making American railroad tariffs. The average railroad traffic manager is usually obliged to say that any tariff which would fairly meet requirements of small carload shippers, and offer due encouragement to those who would load cars to capacity, would be altogether too complicated. And the same traffic manager is also likely to say that it is difficult, if not impossible, to change rules and practices which have obtained for long periods of time and on which business has been organized and built up. He will further say that the graduation of rates on carload shipments according to weight loaded, could not be made without loss of gross revenue, because the carload rates are now subject to minimum weights, which usually represent about 50 per cent. of the average car capacity, and any attempt to increase the rate on small carload shipments would meet the protest of shippers and the veto of state and federal authorities. It would be possible to encourage maximum loading only by offering rates considerably less than the present carload rates. And since the railroads are now able, in one way or another, to get a large proportion of their carload shipments on a capacity loading basis, any attempt to graduate the rates on a consistent basis would certainly result in a loss of revenue.

Some Illustrations of the Wholesale Principle.

Nevertheless, this principle has been to some extent recognized in railroad freight tariffs in this country. The

most numerous examples of such rate-making are found in tariffs of the so-called trans-continental roads. In the case of canned salmon and several commodities which are commonly carried eastbound, these roads make two rates. For example, the rate on canned salmon from Seattle to eastern common points is 85 cents, subject to minimum weight of 40,000 pounds, and 70 cents, subject to minimum weight of 60,000 pounds.

A similar differentiation of rates according to minimum weights has been made to some items in the westbound tariffs of the trans-continental roads with result that nearly all of the tonnage moves under the lower rate, subject to the higher weight, thus proving that shippers can and will accommodate themselves to increased minimum weight requirements if there is any incidental saving in the rate.

Except as the trainload unit may be employed, the carload unit is the only useful basis for estimating railroad transportation cost. When any attempt is made by the railroads to measure the net revenue arising from any traffic, they consider the earnings per car. If the load is 80,000 pounds, the revenue will be twice as much as it would be if the load was only 40,000 pounds. But who will say whether it costs more to transport the 80,000-pound load, and how much more?

Engineering experts have furnished various rules for determining the tractive resistance, or what is commonly called "the drawbar pull" of cars carrying different loads. With knowledge of conditions as to grades, curvature, wind resistance, and so on, these experts can estimate the weight resistance, wheel friction, and all other items to be considered in determining the relative cost of moving a car loaded with 20 tons of freight, and the cost of moving the same car loaded with 40 tons of freight, between two given points under the same conditions. But it has been impossible to state any rule or formula which may be commonly used with confidence. We know only in a very general way that the cost per ton of transporting freight in cars loaded to capacity is very much less than the cost per ton of carrying the same freight in cars half loaded.

An Illustration of Increased Car Efficiency

I hope you will pardon me for referring briefly to what extent the United States Steel Corporation has been instrumental in creating a car supply during the year 1912, by increasing the average carload from 69,200 to 72,400 pounds.

The average carload of outbound traffic for the years 1911 and 1912 for ten of its shipping companies shows the following result:

During the year 1912, the average carload was increased 1.6 tons per carload. This increase of only 3,200 pounds to the average carload on outbound shipments means that there were 76,105 fewer cars used to handle an equal tonnage as compared with the average carload of the year 1911.

Both the shippers and the railroads were benefitted to almost an immeasurable extent in the switching and weighing avoided, namely, the great saving in operating expenses, switching service on 76,105 cars, or 152,210 terminal movements, and the expense of handling this additional number of both empties and loads through the various classification and interchange yards of the railroads, from point of shipment to destination.

The same ten companies last year made a still further increase in the average carload of 1,000 pounds per car, effecting a saving on the outbound shipments for the year 1913 of 35,840 cars. To illustrate, one company saved 122 cars by loading only 100 pounds heavier per car during the year. The record of another company emphasizes the importance of heavier loading perhaps more than any other example, for with an increase of only 400 pounds per car on its traffic means that 15,836 fewer cars were required to move the same tonnage.

The average time consumed by a freight car has been estimated by railroad students at 15 days for each trip throughout the country generally. On this basis a freight car should make twenty round trips a year; so that the 76,105 fewer round-trip cars means an actual increase in the car supply of 3,805 cars, and is equivalent to the creation of a car shop with a capacity to build that number of cars annually.

Taking the basis of $2.25 as the average gross earnings of a freight car per day, and the movement for the average car as occupying 15 days, the earning power of each car would be $33.75 per trip. The additional equipment that would have been required to handle this traffic, 3,805 cars, and this number of cars actually saved, can be estimated in value to the railroads by the earning power, for they were in use in other lines of traffic. Based on the average earning power of $33.75 per car per trip, there resulted $2,568,375 increased freight earnings to the railroads without the expenditure of a dollar for additional equipment.

This actual saving may be figured in another way, namely, the value of 3,805 cars at about $925 per car, would amount to $3,500,000, which represents an investment that the railroads were not compelled to make.

This is an actual record of what has been done, and shows what really could be accomplished throughout the country. It gives some indication of what enormous sums of money could be saved in operating expenses, which is the right way to increase net earnings without increasing the freight bills to the public, or decreasing the payroll for the employee.

Figure this in any manner that you may, it will prove conclusively the money value of conserving the freight car equipment, not only when there is a car famine, but at all times; and any plan that will increase the average carload will do more for car efficiency than anything else.

The Meaning of This to Pittsburgh.

Consider what the shippers of the Pittsburgh District generally could accomplish in the way of creating a car supply by increasing the average load per car. Based on the total Pittsburgh District tonnage for the year 1912, an increase in the average carload on approximately the same basis as the record referred to, of, say, two tons per car, would have resulted in the same tonnage moving in 409,524 fewer cars.

While the Pittsburgh District tonnage is merely used for a basis of computation, there can be no question but that even a more remarkable showing could be made in

increasing the average carload throughout the country generally, if the railroads would bring this subject before the shipping public. Shippers and consignees will be convinced that it is to their best interest to go to additional expense, if necessary, both in loading and unloading heavier cars, when they are made to realize that it means increased car supply; for there is nothing that interferes more with the general business of the country than a shortage of cars.

The ten companies referred to, went to a great deal of extra expense in building up the heavier loads, for it required not only additional labor, but took more lumber for additional car stakes and braces. However, the expense involved can be considered a good investment, for the return was four-fold, as indicated by the items above mentioned.

A Specific Illustration.

While this record for loading is away ahead of the average throughout the country, there is still a great deal of room for improvement. Take, for instance, the record made last year at National Tube Co. dock, at Lorain, in shipments of iron ore, where the average carload for the year 1912 was 96,312 pounds per car, and for the year 1913 it was 107,520 pounds per car, an increase of 11,200 pounds per car. I hope you will pardon me for referring to this dock specifically, but in the year 1912 it occupied the eleventh place in the average carload of the fourteen ore shipping docks on the south shore of Lake Erie, and in 1913 it occupied first place.

If we had followed the 1912 practice of loading, it would have required 6,903 more cars to have moved the ore that was forwarded during the twelve months of last year. There was 2,230,981 tons shipped (the largest quantity ever forwarded over this dock), an increase of 18 per cent. in tonnage with an increase in equipment used of only 2 per cent.

A Suggestion to Railroads.

It seems to me that the traffic officials of the railroads have it in their power to improve the situation in a very

simple manner, by issuing graduated commodity rates based on increased carload minimum weights, i.e., commence on the present basis of rates with the present minimum weights and have a table of higher minimums with lower rates.

For instance, from Seattle to New York, the table of rates on lumber could be made as follows:

Minimum Weight.	*Rate.*
20,000 pounds	$1.25 per 100 pounds
30,000 pounds	.85 per 100 pounds
40,000 pounds	.75 per 100 pounds
60,000 pounds	.60 per 100 pounds
80,000 pounds	.50 per 100 pounds

The present freight rate on lumber from the Pacific Coast to New York is 75 cents per 100 pounds, with 25 or 30 minimum carload weights that are based upon the cubical capacity of the car. The same method could be used by establishing graduated rates in the opposite direction, westbound. Take, for instance, the iron and steel commodities that are produced in large quantities in the East and needed along the Pacific Coast.

Objections might be raised to the large number of carload minimum weights and various rates. To avoid this, the suggestion has been made by Henry S. Prichard to use, for instance, the same minimum weights and basis of rates that are in effect to-day, charging for the excess weight over the prescribed minimum carload weight, say, one-fifth of the tariff rate. Applied to the above example, under the Prichard method, $1.25 per 100 pounds would be charged for the minimum of 20,000 pounds, and 25 cents per 100 pounds for the excess over the minimum, and the total resulting revenue would be the same as in the graded table above.

A similar schedule of graduated rates could be established between any other points and upon any other class of traffic, and perhaps even better examples could be made with flour and grain rates that are in effect to-day.

Transcontinental Transportation.

All will agree that the method of making all-rail rates to the Pacific Coast must be entirely changed if eastern manufacturers are to enjoy any share of the Pacific Coast trade. To see this clearly, it is only necessary to bear in mind the recent large reductions in import duties and ocean freights, and the near approach of the opening of the Panama Canal, which will, if present all-rail rates of freight are maintained, shortly deliver the entire business to British, German, and Belgian manufacturers. Very much of the business has already been delivered to them because of the causes named. But it seems to me that the railroads, by promptly adopting some such plan of making rates as I have illustrated, can hold the business for themselves and for American manufacturers and do so at a substantial direct profit. This will further have the beneficial effect of equalizing their traffic east and west.

Some people may reach the conclusion that this is a drive to lower freight rates. But if it does lower rates it spells increased net earnings for the railroads, because every buyer in the land would specify the very largest carload in every instance, hence heavy loads. The result would be an actual saving in freight costs to the shippers that would compensate them for building up the heavier loads, and, at the same time, result in a marked increase in net earnings to the railroads.

With a graduated schedule of rates to select from, the low minimum carload shipments would become the exception, and the small capacity cars would disappear entirely. There would be three of the present minimum carload shipments forwarded in one car.

To fully appreciate the value of this saving in equipment, consider the following items:

First. The more desirable traffic to the railroads means lower cost of transportation and naturally lower basis of freight rates.

Second. The saving in switching expenses, avoiding congestion in the freight yards and expediting the movement of cars, both for the shippers and the railroads.

Third. The value to the railroads in having an enormous increase in the car supply without the investment of any additional capital.

Fourth. The actual saving to the railroads, in dollars and cents, of the cost of a large number of cars, and the additional saving in operating and maintenance expenses, and the valuable track room in terminal yards. The heavier loading of cars will, in itself, really create increased terminals without the expenditure of a dollar by the railroads.

For months past we have all, I have no doubt, been watching with a great deal of interest the effort being made by the railroads generally to secure permission from the Interstate Commerce Commission to charge rates of freight that would give them sufficient revenue to operate their properties properly, and give the public the service that the public is entitled to, and demands. The strongest argument that has been made in opposition to the views of the railroads, has brought forward the fact, that the railroads could themselves largely increase their net earnings by the practise of various economies. And, while I am not here to argue the rate case pro and con, I know of nothing that has been advanced in the field of economics that would do more to stop the present waste of our transportation facilities, than some such basis of rate-making as enumerated above. There are untold values of railroad equipment to-day that are not being utilized to their capacity or greatest efficiency because we are bound by an antiquated system of rate-making.

Seriously, I believe that the members of the American Iron and Steel Institute can do a great deal toward greater car efficiency by taking up the campaign for heavier loading of cars that will naturally encourage the railroads to build cars of very much heavier capacity, and I ask your cooperation in this movement, which, viewed from the standpoint of transportation, commerce, economies or efficiency, seems to spell Progress.

TRANSPORTATION

DELOS W. COOKE

Vice-President and General Traffic Manager, Erie Railroad Company, New York.

If it may be assumed in my brief discussion of Mr. Townsend's admirable paper that I represent railroad transportation, the compliment he pays the importance of our industry is hereby acknowledged, and he may be assured of our keen appreciation of the great service he is rendering us in his earnest, persistent and intelligent advocacy of the heavier loading of cars. Furthermore, no greater satisfaction could be given me than to point out, as I shall undertake to do, the service he is incidentally rendering the great interest he represents by requiring on the part of the railroads a tremendous increase in the use of steel.

The movement toward cars of larger capacity undoubtedly originated in a desire to economize in transportation cost. Whether this was the desire of the prosperous line to increase its profits or was forced on the weaker lines, as a clever lawyer once said, "By the scourge of crass necessity," is of little consequence; it was sound business policy.

With it, however, came the building of heavier power. The old-style car with the wooden under-frame and weak draft gear connections passed out because it would not stand the strain of the hundred-car train. The car that took its place is of steel or steel frame construction. The most natural thing in the world was to increase its capacity since the structural strength was there of necessity.

ADAPTING CARS TO LOADS.

If the master minds of the earlier day who decided upon and built the large car were disappointed that the carload did not increase in proportion to the increased capacity, the truth may here be stated that when they built the large car they probably gave commercial conditions little or no con-

sideration. They knew that if they had the car so constructed that it could be hauled in the longest possible train, somebody would be very busy trying to find a load for it no matter what its capacity might be. This had to do chiefly with the box car, which probably sees the greatest variety of service, but encouraged by the co-operation of shippers we are now building cars of seventy tons capacity for the iron and steel trade without a block of wood in them. The railroads must carry everything from feathers to pig lead, and, as Mr. Townsend says, commercial conditions—and it might be added the character of the commerce—govern the load.

The car of large cubic capacity is of great service to the railroads in enabling them to increase the load of light and bulky articles, which the varied character of commerce compels them to transport. It is practically impossible to secure a rate that will compensate for the light load on such traffic, but large cars will do much toward helping the situation in cases like:

	Average Carload.
Automobiles	12,000 lbs.
Excelsior	20,000 lbs.
Hay, Straw, Canteloupes	22,000 lbs.
Rags and Waste Paper	23,000 lbs.
Sisal	24,000 lbs.
Agricultural Implements	33,000 lbs.
Apples	26,000 lbs.
Grapes, Cabbage, Tobacco	29,000 lbs.
Oranges	28,500 lbs.
Onions	30,000 lbs.

Progress is being made, however, in securing heavier loading. On one trunk line the average loading on brick is 70,180 pounds, where the average minimum is 40,000 pounds, and on the same line the average on wheat is

71,463 pounds, the average minimum being 60,000 pounds. The average load of iron and steel on another trunk line which handles most of that traffic is 60,000 pounds, showing that there is still room for improvement.

Some Difficulties in Carload Ratings.

If the carload unit were the universal basis of commercial transactions it might be less difficult, even in these times, to endorse Mr. Townsend's suggested basis of scaled rates for increased loading; but the fact that in all big business the carload unit has little to do with the basis of sale, makes it seem that the already unjustifiable spread between carload and less-than-carload ratings is as far in rate reduction as the railroads can be expected to go.

There can be no doubt of the soundness of Mr. Townsend's suggestion, that the scaled rate would induce heavier loading in many lines of traffic, but this is by no means free from danger, especially in the mixed carload. The Supreme Court has decided that a railroad has no right to question the ownership of the goods in the application of carload ratings. This is developing the so-called forwarder or scalper to an extent that is positively startling, and it must be in some way corrected. Recent instances show that these forwarders by consolidating less-than-carload shipments of miscellaneous merchandise into carloads, and thus securing the carload rate, have a margin of 45 cents per 100 pounds, New York to Chicago, to divide with their patrons, making the railroad losses in many instances, as compared with their less-carload rates to which they are entitled, over $100 per car. The loading secured by the forwarders is more than double the average merchandise loading of the trunk line railroads, and the scaled weight basis applied to this traffic would simply increase the profits of the scalper and diminish those of the railroad. In this situation we have the anomalous condition of the railroad being required by law to publish and maintain rates for certain quantities, while the scalper with no investment and absolutely no responsibility is able to make rates as much as 50 per cent. less than the railroad over

the same line and divide his profits with the shipper. This, too, under a decision of the Interstate Commerce Commission sustained by the Supreme Court.

General Conclusions.

The four items of value to the railroads which Mr. Townsend gives as resulting from the saving in equipment are convincing, except as to the first, in which it could not be wholly agreed a reduction in rates naturally followed a reduction in transportation cost.

In the steel business it has been said that there is a bottom but no top. The top on railroad rates is so securely fastened as to make it absolutely necessary to keep any margin of profit intact, if any such thing exists. The railroads cannot afford to reduce their rates even to secure heavier loading, and we must appeal to you to continue your good work in helping us in this direction if for no other reason than it is to your interest to do so.

It needs no argument following Mr. Townsend's paper to show that we *must* get the heavier load, and it is likewise true that the heavier car must be built for the heavier load. The great importance to the iron and steel industry of co-operation in this direction is almost too manifest to permit suggestion, but let it be said that every part of the heavier car, from axle to running-board, calls for an increased use of metal and that metal is steel. The heavy train and the big car call for the big locomotive. A line I know has just built one containing 853,000 pounds of steel, which is capable of hauling a train of loaded freight cars four and three-quarters miles long, *if the cars would stand it.* Bridges have been strengthened to the extent of 30 per cent. axle-load capacity in the past ten years, which means that most of them have been renewed with steel.

Heavier rails and fastenings call for steel, steel.

Have we not found in this, therefore, the ideal basis for co-operation between our great industries? You have only to do your part. We *must* do ours.

RECENT PROGRESS IN THE BUILDING OF LARGE STEAM TURBINES

Francis Hodgkinson

Engineer, Westinghouse Machine Company, East Pittsburgh, Pa.

The author is gratified at the Institute's request for a paper on the development of the large steam turbine. Indeed, he feels that this paper which will treat of the Westinghouse turbine with which he has been identified, might well be followed by similar papers on other makes of turbines, thus laying before the engineers of the steel industry a somewhat intimate knowledge of their features of design—these papers to be perhaps followed later by discussions covering the application of steam turbines to various steel mill uses.

It is generally true that up to the present time, the economic advantages of the steam turbine in its various forms have not been fully employed by the steel companies. The large public utility companies, whose product is power, have been compelled to employ every possible resource to cheapen power production. In that field the turbine has naturally found its chief development. With the steel companies power has been but one of many problems, and perhaps a relatively insignificant one. In consequence they have not reached the efficiency of power plant operation that has been reached by our modern central station plants. However, the bearing which this subject has upon the cost of power production carries its own suggestion.

A historical review here of the development of steam turbines covering the period since their inception in this country would be neither proper nor interesting. However, some reference must be made to the early machines to show the lines along which improvements have been made. The author is desirous of referring to the matter, also, because of public statements which have been made, intended to

show that the last fourteen years have seen the steam turbine brought to its present state of development from a very poor and uneconomical machine. This is by no means true as to the turbines about to be described. The earliest ones compare not very unfavorably with what can be done to-day with similar speeds and capacities. Unquestionably, improvements have been made in producing less expensive and more reliable detail design. Improvements in economy, however, have been due to increased speeds for a given capacity rather than to any material change of thought or principle as regards turbine systems. Very material advances have been made in the development of the high speed alternating current generator which have permitted turbines to be designed more appropriately for the volumes of steam involved. To-day, 5,000 K.W. 60 cycle machines have been built operating at 3,600 R.P.M., while in 1900, electrical engineers looked askance at such speed even for 500 K.W. units, and regarded 1,800 R.P.M. as a more desirable speed for this capacity and frequency.

The principal field for the steam turbines has been driving alternating current generators; and as there are, broadly speaking, but two frequencies in conventional use in this country—25 and 60 cycles—the speeds available are limited. Because of the difficulties of electrical transmission, there has not been much demand for direct current generators of large size. Further, because of the difficulty of designing direct current generators for high speeds, the number of direct current turbine installations is comparatively small. In the installations made of direct-connected turbines and direct-current generators, the speeds selected have been too high for successful operation of the generators and too low for the economical operation of the turbines. Within the last two years, however, reduction gears have been developed which remove this objection; so that to-day first-class designs of direct current generators may be driven by turbines as successfully as alternating current units. A number of such geared outfits have been installed giving entire satisfaction, the speeds being as follows:

Capacity K.W.	Turbine Speed R.P.M.	Generator Speed R.P.M.
150	6,000	900
300	3,600	900
500	3,600	720
1,000	3,600	514
1,500	3,600	360
3,750	1,800	180

The generator speeds given above are standard for motor-generator sets. The last unit named is about the largest size of direct current generator that has been built.

The First Turbine Installations.

The first turbine installation of any importance in this country was made in 1899 at the works of the Westinghouse Air Brake Company. The units were 400 K.W. capacity. About 70 machines of this design were subsequently built. A number of these units were tested and the following may be taken as typical of the results, operating with 150 pounds pressure, 100° superheat, 28-inch vacuum and 3,600 R.P.M.

Load in B.H.P.	Pounds Steam per B.H.P. Hour
264	14.48
445	12.87
593	12.05
759	12.06

In 1900, a machine of 2,000 K.W. capacity, operating at 1,200 R.P.M., was built. This excited considerable comment, particularly in Europe, because at that time it was the largest machine constructed with only a single cylinder. It was regarded by European engineers as a big undertaking and they expected that such a machine would be subject to severe distortions due to its great size and the large range of temperature involved within the single structure. It happened that at that time, machines were being built in Europe of 1,000 K.W. capacity in which two separate turbine cylinders were employed. These were coupled tandem fashion, the steam passing serially through them.

Greater security was no doubt assured by the two cylinder arrangement, since the two structures were so much smaller, and also, because of the smaller temperature range involved in each. It is interesting to note that our experience with the large single cylinder machines led us to copy foreign practice in constructing machines with two cylinders for large capacities, while they in turn were encouraged to build larger machines of single cylinder construction.

Two Cylinder Turbines.

In 1903, about sixteen two-cylinder machines were built by the Westinghouse Machine Company, ranging in capacity from 1,000 to 2,000 K.W., from 1,200 to 1,800 R.P.M., all of which gave excellent results from every standpoint. One reason that led us particularly to the two-cylinder design was the fact that at that time, reheating receivers were very fashionable among builders of reciprocating engines, and while we did not think reheaters were of particular value in connection with reciprocators, we did expect a substantial gain due to the reduction of moisture content in the steam passing through the low pressure elements. Careful tests showed that the gain in economy was slight when the live steam used for reheating was charged up against the machine and that the gain in economy did not warrant the increased investment. Results of typical tests on these machines operating with 150 pounds pressure, 75° superheat, 28-inch vacuum and at 1,200 R.P.M., are given below:

K.W. Load	Pounds per K.W. Hour
198.4	31.76
333.15	25.39
977.14	18.59
1,274.20	17.66

These two cylinder machines are of interest because at the present time there is a reversion to this construction for large machines. This system was employed by Mr. Parsons for the 20,000 K.W. machines lately furnished the

Commonwealth-Edison Company, of Chicago, and has also lately come to be used by other manufacturers in this country. The principal objection to the design is the great length, due to the increased number of bearings, etc., and the high cost.

Return to Single Cylinder Practice.

Further experience led to the abandonment of the two-cylinder design and the adoption of single cylinder machines for all sizes which were at that time built, which up to 1905 included machines of 7,500 K.W. capacity. At this time, there was little demand for 60 cycle units in large sizes, there being hardly any machines sold of over 2,000 K.W. capacity at this frequency. Conditions differ materially to-day; some of the largest machines now being sold are for 60 cycle service.

As already stated, turbines were limited in speed by the restrictions of the generators, and at this time (1905), the following may be regarded as the speed limits:

60-Cycle Service	R.P.M.
Up to and including 500 K.W. capacity........	3,600
Up to and including 1,000 K.W. capacity........	1,800
Up to and including 3,000 K.W. capacity........	1,200

25-Cycle Service	R.P.M.
Up to and including 3,000 K.W. capacity........	1,500
Up to and including 7,500 K.W. capacity........	750

All these machines were of the straight reaction design, the general character of which is shown in Fig. 1.

These machines were equipped with a regular fly-ball governor, controlling the turbine by means of a steam relay mechanism which admitted steam to the turbine in puffs. This system of control, while exceedingly sensitive and giving excellent regulation, has been found objectionable in some cases, particularly with the largest machines, on account of the interruptions to steam flow tending to cause reactions and vibration of the steam lines. The system, however, has this advantage, that the cylinder walls absorb heat from

the steam more quickly than they give it up. Consequently the temperature of the cylinder walls is higher than the average temperature of the steam, permitting an increased steam flow due to sudden increase of load to take place with less condensation. The continual motion of all valve and governor parts precluded any sticking, hence sensitive and close regulation was attained.

Normal and Maximum Rating.

These turbines were for the most part sold on what is known as the "normal rated" basis. The turbine carried a certain normal load, and the generator would usually carry that same load with a 40° rise. The generator would further carry continuously, 25 per cent. more load with a 50° rise, and 50 per cent. more load for a limited time—generally one hour—with a 60° rise. This is somewhat different from the practice of to-day when machines are sold at their maximum continuous rating or thereabouts. In these early days, the turbine was in competition with the reciprocating engine, and the turbine builder was called upon to do the things which the Corliss engine builder had been accustomed to do, namely, to have the point of best efficiency at some relatively low load, and means of carrying heavy overloads in excess of this. It is now customary to sell turbines on a basis of maximum rating. Unfortunately this leads to considerable confusion, as the maximum rating is no real indication of the actual size of the machine. As has been said by one writer, the business has begun to partake of "bargain counter methods." However, as different power plants have quite different requirements as to the relation between the point of best steam consumption and the maximum overload, it is not a matter which may be readily standardized.

So far as the generators are concerned, the modern system of giving them a maximum continuous rating at 50° rise with the possibility of carrying more load than this for a limited time, has much to commend it, but the matter is different with the turbine.

In a small railroad plant, the units being few and having to encounter certain daily peaks, it is convenient to have units capable of carrying overloads at some sacrifice of economy. Under such conditions, the turbines should have their most economical point at some fraction of the maximum load. Therefore, it follows that for small plants of this character, the conditions would best be met by the old system of rating. To rate such a machine at its maximum capacity is merely a difference in name, but different names cause confusion.

In the other type of power plant, that of a large public service company, with many machines of large size, where if a unit is running at all, it is operating at or near its maximum load, the most adaptable turbine is one which has its point of best steam consumption at from 80 to 85 per cent. of this maximum load—the generator having its maximum continuous rating at this same maximum load.

By 1909 very material progress had been made in the design of generators which reached the possible capacity of turbines arranged single flow, and with the customary blade speeds designed for 28-inch vacuum. It might be here noted that the low pressure blading limits the capacity of turbines. Considerations of centrifugal force fix the diameter of the last disc or drum. With this at a given diameter, there is a limiting dimension of blade which may be employed. A blade whose height is 15 per cent. or at most 20 per cent. of the diameter of the drum is not exceeded. To do so involves losses due to disparity of tip speed and root speed of the blades, there being no steam speeds to best satisfy the two extremes. With the given dimensions of blade passages, the weight of steam which may be passed depends on the desired limit of expansion—the vacuum to which the turbine is to expand and the desired velocity of steam, which latter should bear a definite ratio to the blade speed. In the case of a machine designed for high vacuum, and with blade speeds of 400 feet or more, it is customary for the steam velocity in the last row of blades to approach the critical point at full load—1,200 feet per second.

Double Flow Turbines.

While the limitation of turbine capacity at the low pressure end is that of providing area on account of the large number of expansions involved, the problem at the high-pressure end of the turbine is in dealing efficiently with the very minute volumes of steam there involved. It became evident, therefore, that if the low pressure were made double flow, permitting steam to flow through two low pressure elements in opposite directions, and the high pressure element were to remain single flow, increased capacity as well as higher economies would be obtained. Inasmuch as the number of elements in a turbine are proportional to the heat drop, it follows that a turbine made double flow will have twice as many elements as a corresponding single-flow machine. Therefore, when the low pressure portion was made double flow, in the manner above referred to, the machine became undesirably long, and to obviate this difficulty, the portion of the turbine corresponding to the small diameter shown in Fig. 1, was replaced with an im-

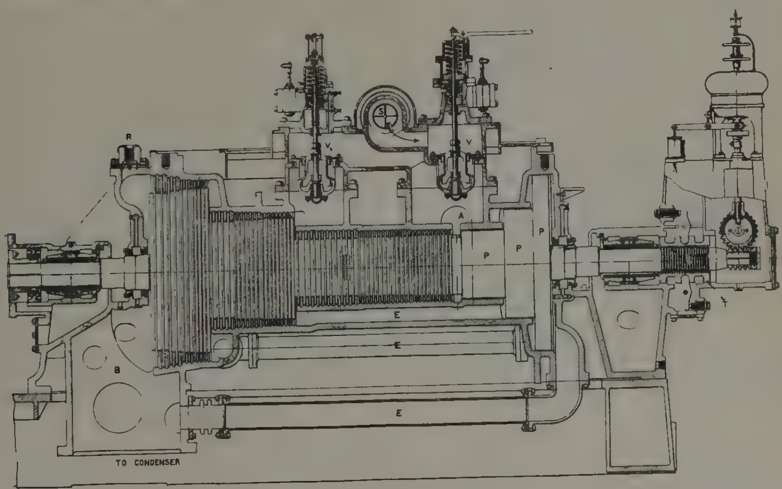


Fig. 1.

pulse element of the Curtis type. This has the advantage of dealing with a given heat drop with less axial length, as well as frequently being as efficient as a corresponding

reaction element in which, on account of the small steam volumes, the blades are small and the leakage ratio relatively high.

The impulse element of the high pressure has a further mechanical advantage of increased flexibility which permits the use of different nozzle areas and proportions, rendering it possible that a standard machine be readily changed to operate with different capacities, pressure and superheat. Inasmuch as a substantial pressure and temperature drop may take place in the nozzles, the employment of an impulse element permits steam of high pressure and temperature to be enclosed within small chambers separate from the cylinder structure. This machine called a "Semi-Double Flow," resolves itself into that shown in Fig. 2. A further increase of capacity may, of course, be obtained by running the low pressure blades at a higher speed and carrying the double flow principle to greater limits, i. e., only the impulse element being single flow, and all of the reaction elements, double flow.

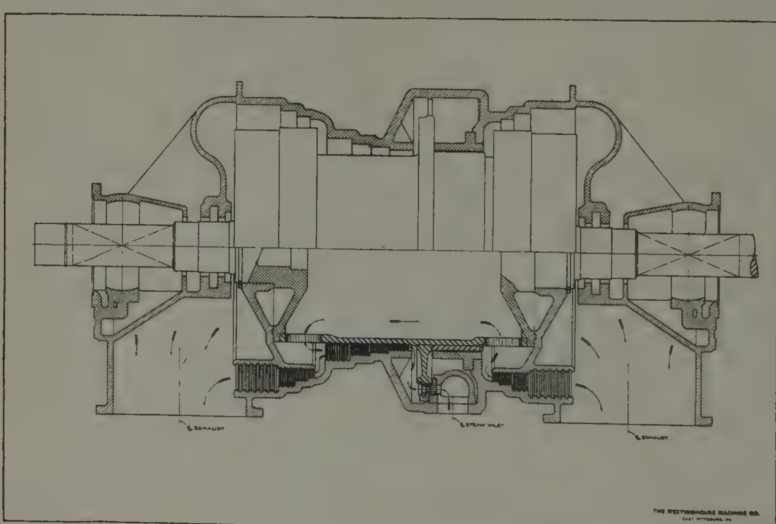


Fig. 2.

The employment of double flow turbines would not necessarily be advantageous were any rotational speed available. If a single flow turbine of given diameter, for

example, were made double flow, the blade passages would require to be of half the dimensions for the same capacity, thus doubling the leakage losses. Therefore, the double flow principle should be employed only where the volumes of steam are such that for mechanical or other reasons, sufficient areas of blade passage at the low pressure cannot be otherwise obtained. It should be remembered that if a speed be selected which is low enough to permit the low pressure blading being single flow, the speed would be far too low for the best design of the high pressure portion.

These limits of capacity, of course, apply to turbines designed for complete expansion in the blades in the case of reaction elements, or complete absorption of steam velocity in the case of impulse elements. By increasing the areas of the high pressure elements, an almost unlimited quantity of steam may be passed through the turbine, enabling it to develop correspondingly enormous horsepowers, but by so doing, either the expansion will not be complete within the turbine blading in the case of reaction turbines or in

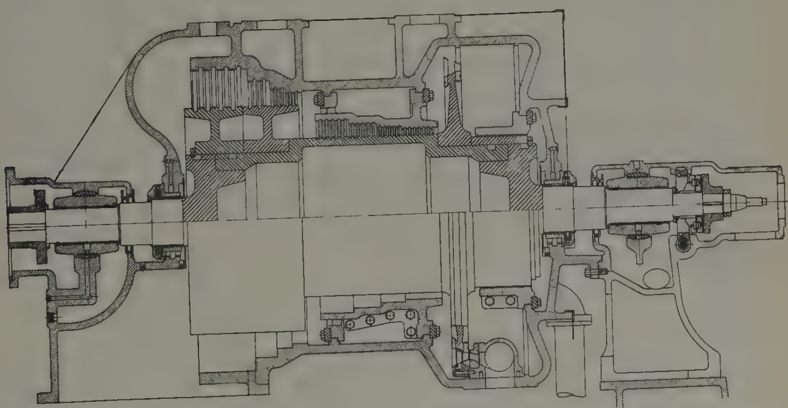


Fig. 3.

the case of pure impulse turbines, the velocity through the last row of blades will be so high with relation to the speed of the blades themselves that there would be losses due to residual velocity in the steam after it has left the turbine. The last row of blades is, therefore, the determining factor,

and the losses involved because of this being too small are precisely the same in any type of turbine.

The advantages of the impulse element for high pressure have been pointed out in the foregoing, and are equally applicable to single flow machines. Therefore, for the smaller capacity machines at the given speed, a single flow combination type machine as shown in Fig. 3 became a natural development.

The following table may be said to represent the limits of speed of standard turbines in 1900:

	60-Cycle Service	R.P.M.
A	1,000 Kw., single flow	3,600
B	Up to 2,000 Kw., double flow	3,600
C	Up to 6,000 Kw., semi-double flow	1,800
D	Up to and including 10,000 Kw., double flow	1,800

	25-Cycle Service	R.P.M.
E	Up to 3,000 Kw., single flow	1,500
F	Up to 7,500 Kw., semi-double flow	1,500
G	In 1909, some 10,000 Kw., 25-cycle machines were built of the semi-double flow type operating at	750

In all of the above, the capacities mentioned are normal ratings, the turbines being for the most part, capable of carrying 50 per cent. additional capacity. A certain number of tests on these machines are available, the results of which are shown in the curves, Fig. 4, the respective machines being identified by the letters given in the above table. All tests are reduced to a common operating condition of 175 pounds, 100° superheat and 28-inch vacuum. "H" is typical of the results obtained in tests on a 7,500 Kw. single flow reaction turbine operating at 750 R.P.M.

Up to this time, it was the general practice to design turbines for moderate vacua only. While purchasers of turbines talked glibly of 28-inch vacuum and better, it was indeed seldom that even 28-inch vacuum was actually maintained in the average plant. Of course, standardization is a factor of commercial success in machinery building, so

that it was desirable to design turbines for the average, rather than the exotic condition. The above-mentioned machines were not capable of expanding the steam materially beyond 28-inch vacuum at full load. Hence the vacuum correction, i. e., the gain in economy per inch of

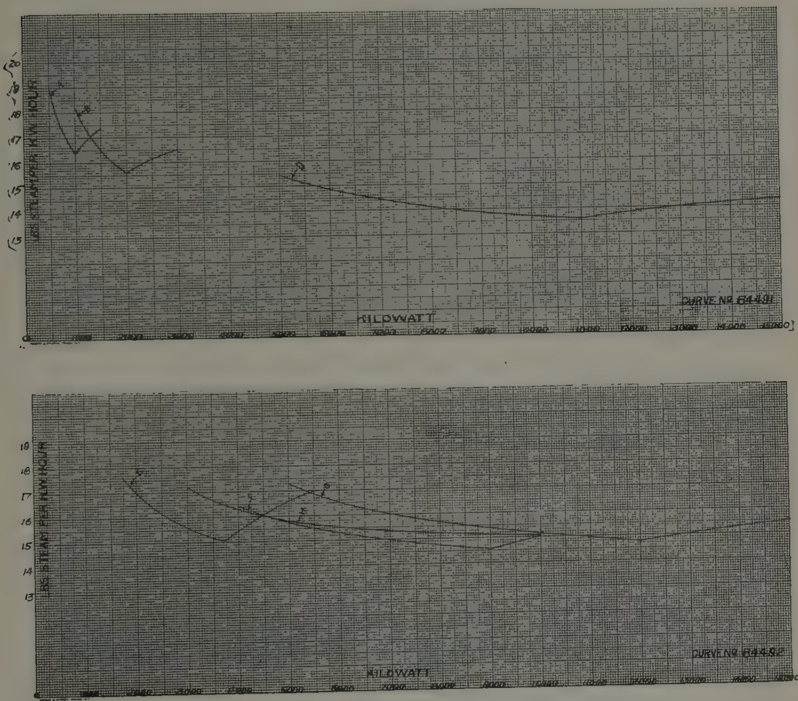


FIG. 4.

vacuum beyond 27 inches was relatively low, approximating 3.5 per cent. at full load. The rapid introduction of turbines up to this time brought with it very material developments in condenser design, making it desirable for large turbines, at least, to expand to 29-inch vacuum.

Losses in the Impulse Turbine.

Before describing the latest machines, some discussion as to the losses involved in the two respective types of turbine elements, viz., impulse and reaction, is in order. The impulse element comprises a nozzle in which the steam is

expanded to the exhaust pressure of that element. There is a complete energy transformation within the nozzle transforming the potential energy due to pressure into kinetic energy. This nozzle is followed by certain rows of blading. If the blades may be operated with about 40 per cent. of the velocity of the steam, one row will economically absorb this velocity and we have the well-known Rateau or De Laval type of turbine. If the blade velocity must be materially less than this, it is customary to employ more rows of blades, the steam leaving the first moving row being redirected by means of guide vanes onto a second row of moving blades. The highest efficiency obtained with this combination is where the blade velocity is about 22 per cent. of the steam velocity. With higher steam speeds and lower blade speeds, three rows of moving blades may be employed per element, in which case the highest efficiency will be obtained with this ratio about 13 per cent. The above is approximately correct with blade speeds of 300 to 500 feet per second. The highest efficiency, however, which may under favorable conditions reach 80 per cent., is obtained with a single row of blades. By using the higher pressure range in the nozzle or lower blade speed, or both, thus necessitating the greater number of velocity elements, the efficiency falls off quite rapidly, so that a three-row velocity stage element is now only used in very extreme cases, such as in the reversing elements of marine turbines. Their efficiency will hardly exceed 50 per cent. The efficiency of the two-row element may be 65 or 70 per cent.

The efficiency of the nozzle itself is of a high order, particularly with small pressure drops, approximating 95 per cent., for 8 to 10 B.T.U., falling off to about 82 per cent. for a 200 B.T.U. drop. The losses in the blades are:

(1) Hydraulic losses, which depend upon the relative velocities, blade angles, etc., and receive the same consideration as in a hydraulic turbine.

(2) Friction and eddies, which increase with the velocity of the steam in the blade passage, and hence become greater with a greater number of velocity abstractions.

(3) The nozzle zone does not generally occupy the com-

plete circumference of the circle. The blades on entering the zone of the nozzles, require that the medium that is stationary within the blade passage be accelerated by the steam leaving the nozzles which reduces the velocity. At either end of the nozzle zone, there are blade passages only partially filled, thus causing eddies, which condition is repeated at each velocity abstraction causing losses known as "spreading."

(4) At times, with the disc type turbines, skin friction on the exposed surface of the disc is considerable, owing to the large amounts of exposed surface. The blades themselves, where only a small portion of the circumference is occupied by nozzles, are an additional source of friction.

(5) Leakage losses in an impulse element are usually very small, and are at the point where the shaft passes through the diaphragms between the respective elements. In turbines herein described, as there is but one impulse element employed, no diaphragms are involved.

Losses in the Reaction Turbine.

In the reaction turbine, which it should be understood technically comprises a series of stationary and revolving nozzles and not blades, the following losses are involved:

(1) Hydraulic losses, which depend on the blade angles, and the ratio of the steam velocity to the blade velocity. This velocity ratio varies from 50 per cent. in the small to 75 per cent. in large units, the hydraulic losses for the above ratios being from 22 to 10 per cent. respectively.

(2) Nozzle losses—as in the case of the impulse turbine these are low. But particularly so in the case of the reaction turbine, because of the many stages and the small B.T.U. drop per stage.

(3) Leakage losses—in a reaction turbine, these form a most serious item, and where the steam volumes are small, such losses may amount to 20 per cent. But in the combination type turbines herein described, where reaction elements are employed for the low pressure portions, the losses become inconsiderable, ranging as low as 5 per cent.

(4) Skin friction, and the losses previously referred to

in the case of the impulse element under items 2, 3 and 4, are exceedingly low inasmuch as the whole of the annulus between the outer diameter of the drum and the cylinder wall is completely occupied with the flow of steam and it is not subjected to the disturbances at the ends of the groups of jets, as mentioned in the case of the impulse elements.

Radiation, bearing friction, etc., are relatively unimportant, and would be the same for either type of turbine element.

It is evident, therefore, that higher economy is to be obtained from reaction elements providing the speed of the turbine and the volumes of steam are appropriate for design with low leakage ratios, and conversely, the impulse element is better for the high pressure end of a turbine where the volumes of steam are small.

Turbine Blades.

Concerning the matter of turbine blading, there has been a good deal of misapprehension, although in earlier years there was considerable apprehension that was fairly justified. With all types of turbines, the design and material of turbine blading have undergone some evolution. Blading, of necessity, is subjected to very arduous conditions. It works in a steam current of considerable velocity, the steam oftentimes being laden with moisture, and sometimes with chemicals and solid foreign particles as a result of priming boilers. Centrifugal stresses must of course be properly considered but far more important is the fact that any design of blading in any design of turbine, must be able to withstand, so far as may be, the tendency to vibrate in the steam current. The characters of the two salient types of turbine elements, impulse and reaction, require quite different blading; the one, massive blade sections and the other, a relatively light section. However, the strain on the blades due to centrifugal force is the same in either case, and in the event of collision, between blades, the one is as subject to injury as the other with the difference, however, that the results of the wreck may be more far-reaching in the case of the more massive blades. In some of the early designs, breakages were

due to contact between the stationary and revolving elements resulting from distortion of the cylinder structures. This has been eliminated by the better design of these structures, the elimination of ribs and all unnecessary excrescences which might lead to internal strains in the castings or distortions due to uneven heating and cooling.

The principal cause of breakage of turbine blades is vibration in the steam current. There are scarcely any records of blading having broken because of centrifugal force *per se*. Shrouding and other means of bracing the outer ends of turbine blades to each other have been employed to reduce

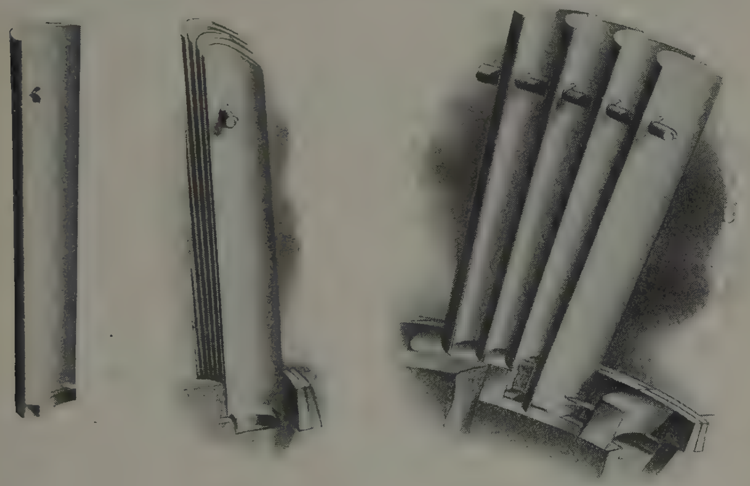


Fig. 5.

the tendency to vibrate. Such devices raise the natural period, and hence reduce the amplitude, of vibration but do not completely eliminate it. Later designs of blading have their sections tapered, there being some 40 per cent. more area of cross section at the root than at the tip. There may be some vibration with this construction but the deflection will be distributed over considerable length instead of being concentrated at the point of attachment. The later method of attaching reaction blades is shown clearly in Fig. 5, the blades having a foot forged on the end which fits in a groove that is in the floor of the main groove of the blade carry-

ing element. The spacers between the blades are dovetailed to correspond with the dovetailing of the main groove, thus completely interlocking the blading and rendering the attachment as strong as the blades themselves. Larger blades like those shown in the illustration have their grooves provided with compound wedges which help to more completely fill the grooves. We commenced to employ this type of blading in 1911, and with this type, have experienced no breakage due to vibration.

Supplementing the table in the foregoing, giving the speeds employed in 1910, the speeds involved to-day, are as follows:

60-Cycle Service	R.P.M.
Up to 1,000 Kw. capacity, single flow	3,600
Up to 4,000 Kw. normal and 5,000 Kw. maximum capacity, double flow	3,600
Up to 6,000 Kw., semi-double flow	1,800
Up to 12,000 Kw., normal, 15,000 Kw. maximum, double flow	1,800

25-Cycle Service	R.P.M.
Up to 3,000 Kw., normal, 5,000 Kw. maximum, single flow	1,500
Up to 7,500 Kw., normal, 10,000 Kw. maximum, semi-double flow	1,500
Up to 10,000 Kw. normal, 20,000 Kw. maximum, double flow	1,500

In 1913, a number of contracts were taken for machines ranging in capacity from 15,000 Kw. maximum to 22,000 Kw. maximum. Those for 25-cycle service operated at 1,500 R.P.M., while the 60-cycle, 15,000 Kw. maximum rated units ran at 1,800 R.P.M. In all these cases the complete expansion was carried out within a single cylinder. Complete description of these machines is given, inasmuch as they represent the latest design of machines of large capacity at the given speeds, designed for 29-inch vacuum. These types are precisely similar in their design characteristics, and one description will serve equally well for both, as

well as for the 5,000 Kw. maximum rated machine operating at 3,600 R.P.M.

Fig. 6 is a longitudinal section through the machine, the steam passing single flow through the impulse element which operates at 400 feet to 450 feet per second, expanding the steam to approximately 70 pounds absolute, then passing

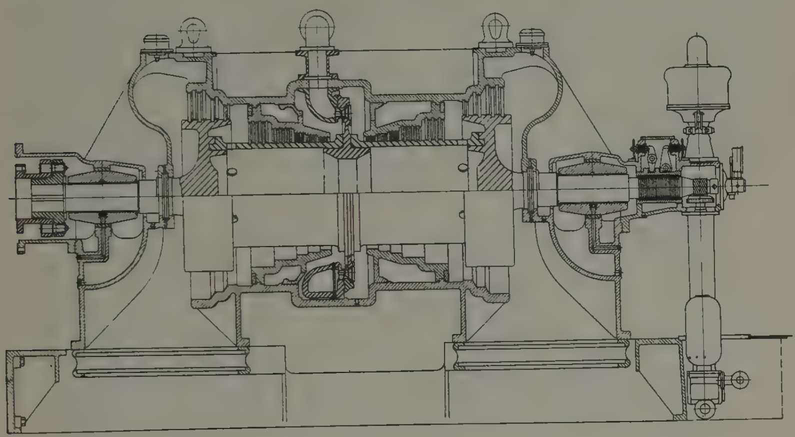


FIG. 6.

through the reaction elements double flow. Because of the large capacities of these machines, the blading of the low pressure end runs at higher speed than had heretofore been customary, viz., 500 feet per second.

DETAILED DESCRIPTION OF PRESENT DAY TURBINE.

The construction of the disc carrying these blades is original in the respect that it is forged or cast in one piece with the spindle end and partakes of the nature of a solid disc without any perforations. With this construction, the stresses are comparatively low permitting with entire safety, the use of ordinary steel forgings and occasionally, castings of low grade nickel steel.

Spindle.—The construction of the spindle is apparent, the strong central drum giving great rigidity, and a calculated deflection of .007-inch. An external view of the finished spindle is given in Fig. 7.

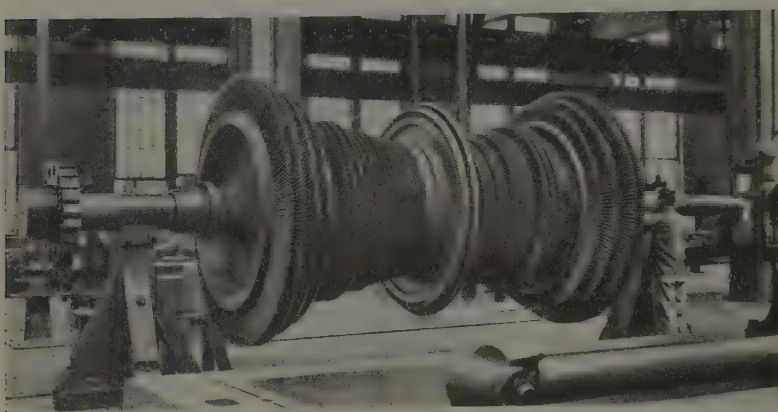


Fig. 7.

Nozzle Blocks.—The nozzle blocks are of steel, entirely separate from the main cylinder structure, being bolted to the interior. Their general disposition is as shown in the cross section, Fig. 8.

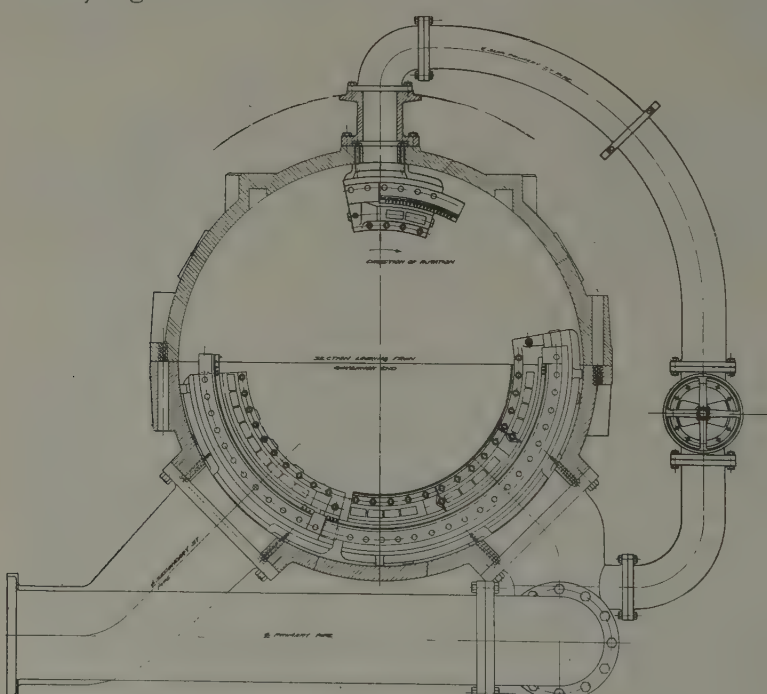


Fig. 8.

Cylinder.—Every step has been taken to maintain the cylinder structure of simple form, with few changes of diameter, and with no feet or unnecessary excrescences. Tending towards this simplification, it should be noted that only the last few rows of blades are carried in the cylinder proper.

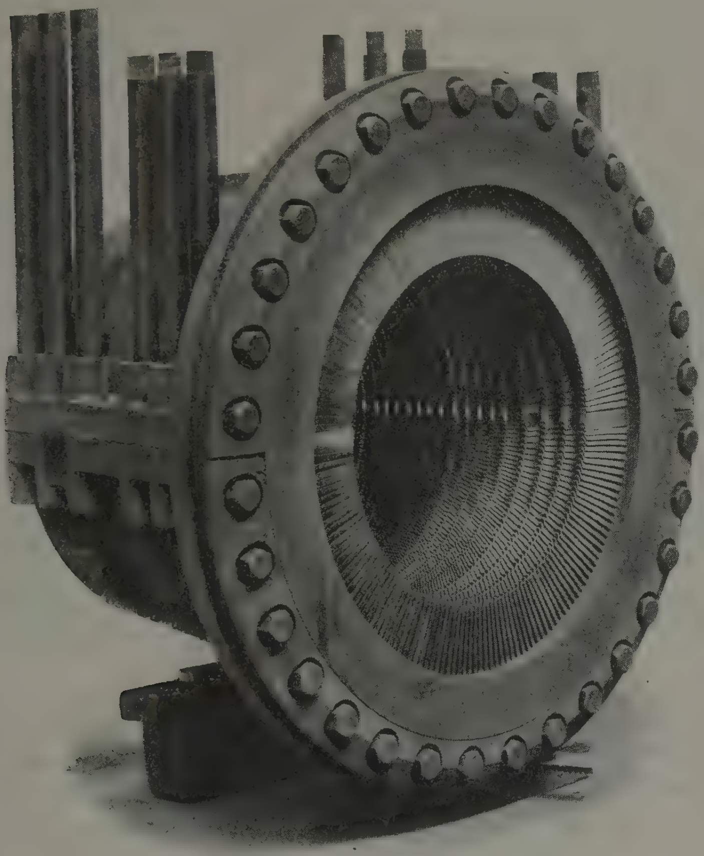


FIG. 9.

The intermediate blade carrying element is entirely separate from the cylinder, thus eliminating all flanges and ribs which would be involved should these blades be in the main cylinder. One of these blade-carrying rings is shown in Fig. 9.

They may be seen in place in a cylinder cover in Fig. 10. The method of securing these blade-carrying rings to the cylinder is merely to clamp them to a machined shoulder in the inner wall of the cylinder proper. These blade-carrying rings form complete cylinders in themselves, and are bolted together with studs and long nuts as shown in Fig. 9, which reach through apertures in the cover so that in assembling or disassembling, the respective halves of the blade-carrying rings remain in place as though they were cast there. While

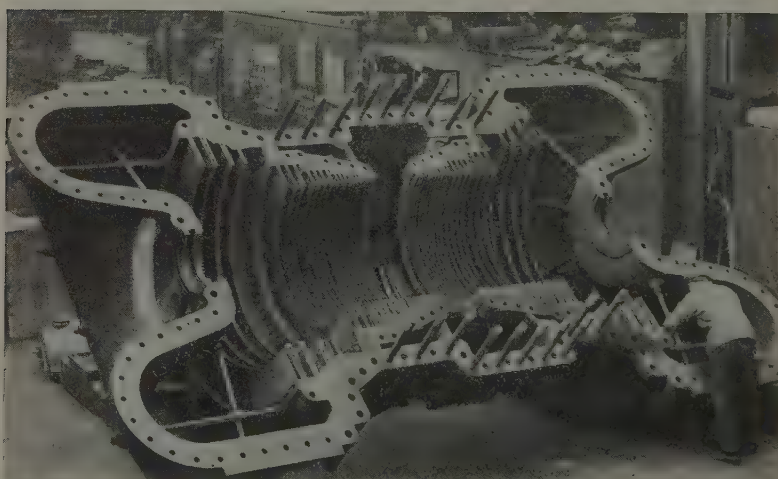


Fig. 10.

this construction has been employed primarily to bring about simplification of the cylinder, the advantage of being able to readily replace any or all of these blade-carrying elements is obvious.

On account of the high vacuum for which these machines are designed, the exhaust chambers are of necessity very large, and obviously on account of the external pressure, there must be ample rigidity. This, of course, might readily be obtained by employing ribs and braces, and the like cast therein. However, for the sake of avoiding internal strains incidental to such construction, ribs are entirely avoided, and steel stays and braces employed.

Expansion Joints.—Expansion joints are always provided on the exhaust connections, and in the case of double flow turbines, they are particularly necessary as the cylinder expands with a different ratio of expansion from that of the top of the condenser. However, expansion joints perform another important function, viz., provide for misalignment of the very heavy piping since generally the flanges do not come together exactly as they should, and by providing expansion joints, this misalignment is permitted without producing stresses in any of these parts. The expansion joints employed, are intended for external pressure only, and their construction is shown in Fig. 6, the corrugations being inwards instead of outwards, as with the usual form of joint. This permits the very largest expansion joints to be made of thin copper, say No. 12 gauge, the copper being in tension without any buckling stresses. The bolting is made up inside of the pipe where there is plenty of room to get at the bolts, which would not be the case if the bolting were outside the flange, where it would come between foundation piers and therefore be inaccessible.

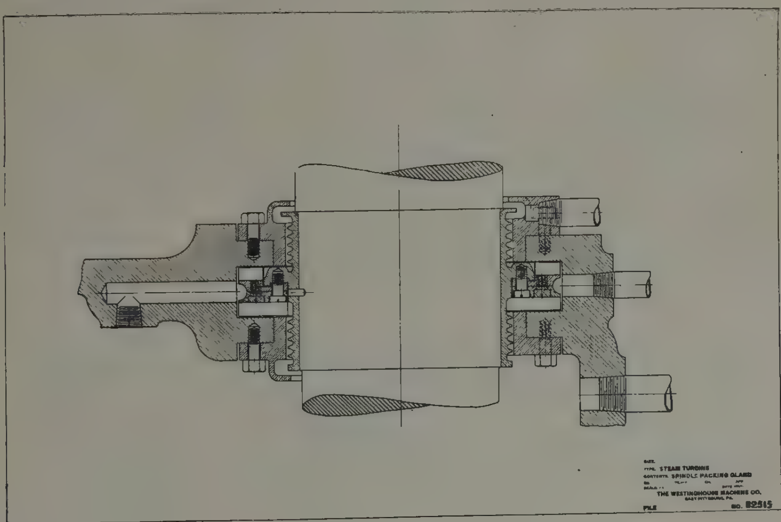


Fig. 11.

Glands.—The type of gland employed, known as the "Water Gland," is shown in Fig. 11. No essential changes

have been made in the construction of this detail for many years. It comprises simply a double centrifugal pump operating in a chamber. It is provided at its periphery with water, say of 5 pounds greater pressure than the pressure against which it is designed to pack, the pump being designed for a pressure ten pounds higher than this, should it be full of water. The pump thus maintains an annulus of water at the outer edge which forms a very complete seal.

Bearings.—These are of the simplest construction, being merely babbitt lined cast iron shells. A flood of oil is provided to a groove that runs along the top. The bearings are made with a standard clearance of .002 inch per inch of diameter. With this construction, it is not known what are the limits of unit pressure or velocity. 80 feet per second velocity is frequently employed, and 120 pounds per square inch of projected area. With these pressures, no wear has ever been experienced. The high speed and method of lubrication insure a well established oil film. The work done in the bearing itself is not the friction of rubbing surfaces as ordinarily understood, but the work of separating the oil particles, which increases with the viscosity of the oil, and some function of the surface speed.

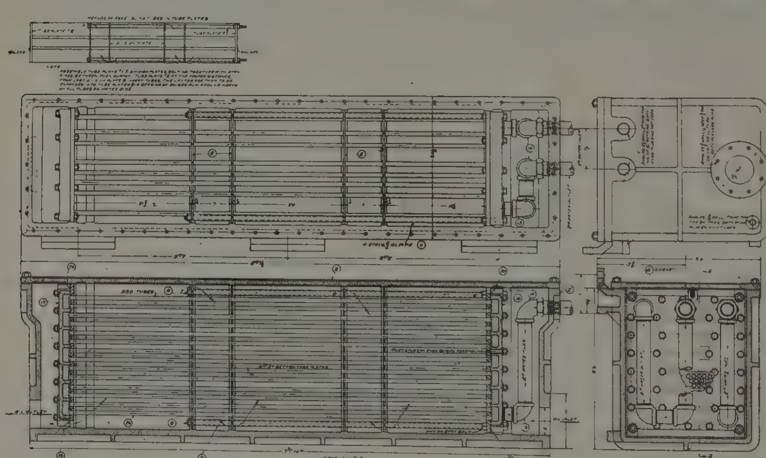


Fig. 12.

Oil Coolers.—With higher speed bearings, more cooling facilities must be provided. No doubt, very effective oil

cooling may be had by water-jacketing the bearings. The unit heat transfer may be exceedingly rapid. However, we have always employed a separate cooler as part of the oiling system which, while a square foot of its surface may be less effective than the rapidly moving thin film in the case of the water-jacketed bearing, has the advantage that it may be very readily cleaned and inspected. The design of cooler employed is shown in Fig. 12.

As the oil in the system becomes hotter, the viscosity goes down, so that with a fixed amount of cooling the system assumes a definite temperature, the rise in the bearings approximating 10° to 20° F. There is a tendency among operators to strive to maintain low temperatures of oil, 100° F., for example. This is obviously a wasteful procedure, only entailing unnecessary loss. 140° F. is an entirely safe oil temperature for indefinite operation.

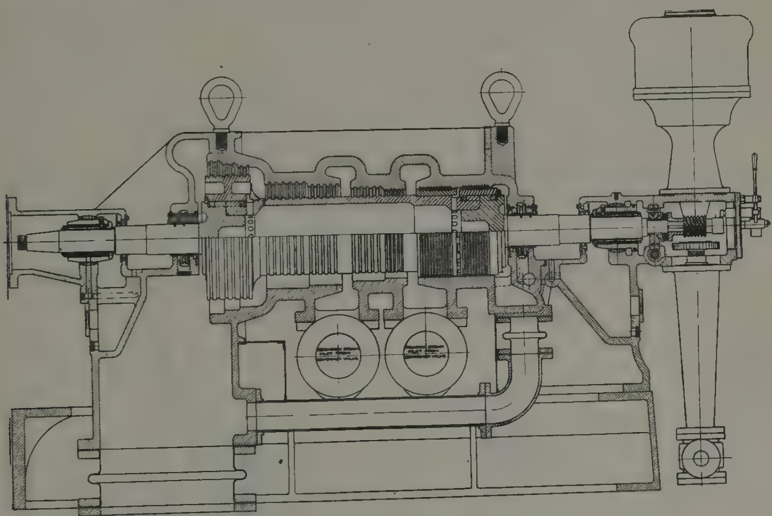


FIG. 13.

Thrust Bearings.—The double flow turbines are entirely balanced, so far as end thrust is concerned, so that nothing is required beyond means for maintaining the rotor in its proper position in the cylinder. Some single flow turbines, however, have lately been built like Fig. 13 in which the balance pistons or dummies balance only a portion of the

end thrust, the remainder being taken on a thrust bearing that has been devised by Mr. Albert Kingsbury, which by its ingenious construction permits pressures to be carried which have hitherto been unattainable with ordinary thrust bearings. With this new type of thrust bearing 500 pounds pressure per square inch is sustained without any appreciable wear. The author has experimentally carried pressures as high as 5,000 pounds per square inch, at which pressure the bearing failed. It did not fail by heating or wiping of the surface but on account of crushing of the babbitt, the babbitt surfaces becoming mushroomed. It is interesting to record that the friction was so slight that the mushrooming took place as much against as with the direction of rotation. Ordinary thrust bearings, which comprise revolving discs and self-aligning rings, will not successfully carry much more than 50 pounds pressure per square inch. This, in fact, is the allowance employed by designers of marine propelling machinery. This is because the surfaces in contact are of necessity parallel with one another, which is an undesirable condition. The desideratum is to admit oil at a given point, where it may by its adhesiveness enter between the surfaces. It will then be subjected to pressure and so spread in every direction and the film squeezed thinner. If the surfaces remain parallel, it would be only at the point where the oil enters, where the load would be sustained. If, however, the surfaces be permitted to incline to each other, so that as the oil is drawn across the surfaces and the film thickness become thinner, the load may be distributed over the entire surface. This, it should be noted, is the condition obtaining in the ordinary bearing where the bearing shell is bored a specified amount greater than the journal, the oil film being in the nature of a curved wedge reaching a minimum thickness some few degrees behind the vertical. A photograph of the parts of a Kingsbury thrust bearing is shown in Fig. 14, and an assembly in Fig. 15. It will be seen that the stationary surface is divided into a number of segments—in this instance, eight. Each of these segments is centrally pivoted on a self-aligning ring so that each segment may assume any

angle it pleases, thus permitting the oil film to be of wedge-like form, every square inch of it being effective in supporting load. It is lubricated by merely circulating oil radially

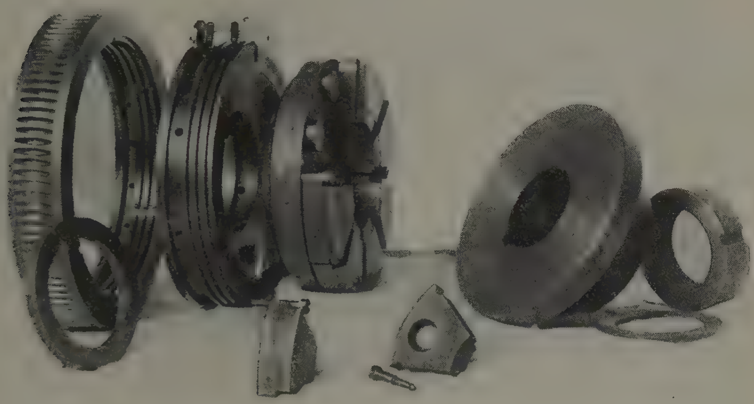


Fig. 14.

through the spaces between segments. The threaded portion on the left with the worm teeth cut in it is merely a means of adjustment as is apparent from Fig. 15.

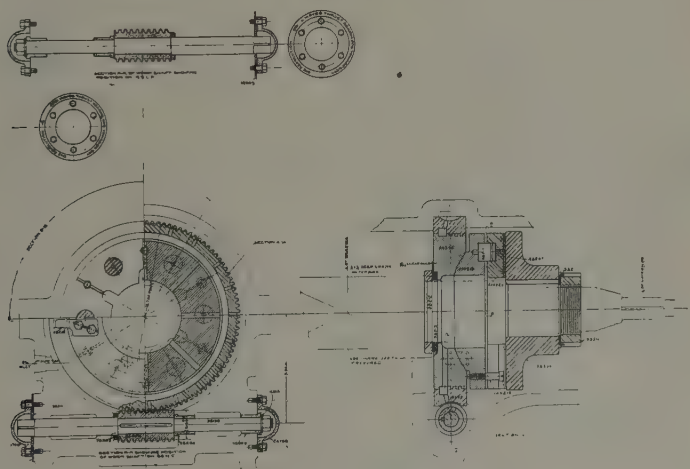


Fig. 15.

Coupling.—The coupling is shown in Fig. 16, the novel feature being to provide circular driving pins with some over-

hang, which may deflect a few thousandths without producing a high stress. With any misalignment between the driver and driven parts, there is an acceleration and retarda-

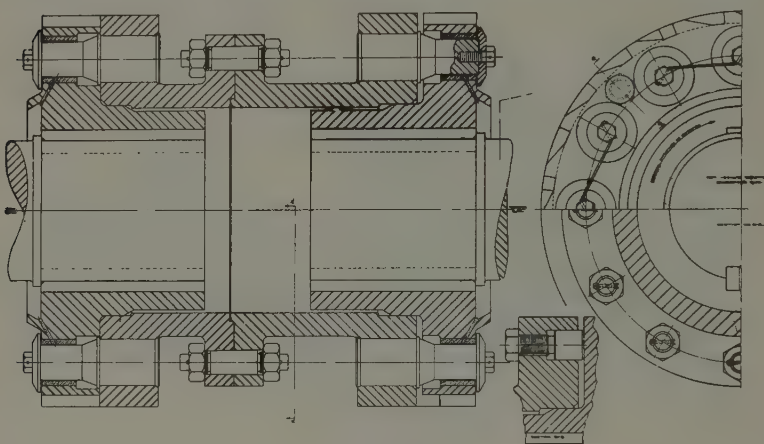


Fig. 16.

tion, which in a few cases with the older construction with rectangular driving horns of great rigidity caused racking and breakage.

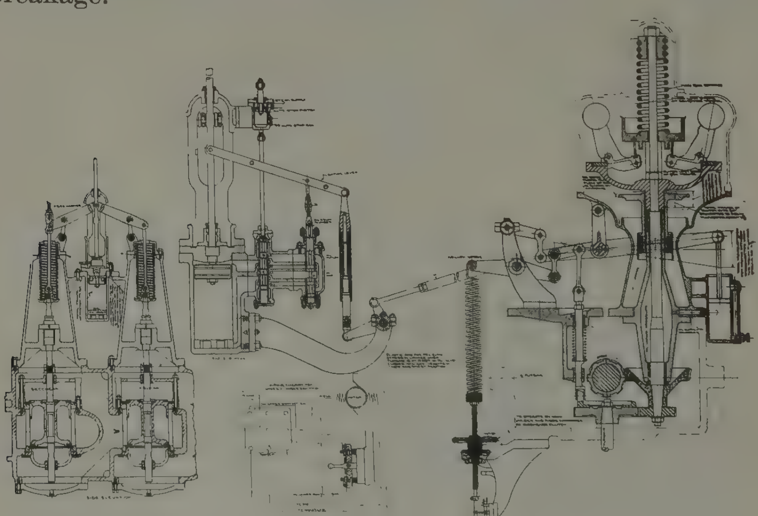


Fig. 17.

Regulation.—The governor is driven, as customarily, by means of a worm wheel from the turbine spindle, the arrange-

ment of which, and its connection to the valves, and the valves themselves are shown in Fig. 17. Although a relay is employed, it is believed that sensitive governing is not to be obtained except with a substantial and powerful governor. These governors have sufficient mass to give a pull of 75 pounds on the clutch, with a 1 per cent. change in speed. All wearing parts of the governor are provided with forced lubrication insuring against wear. The valves themselves, are entirely of steel, except the seats which are of Monel metal rigidly clamped in place, previous experience having shown that cast iron valves have been, even with moderate superheat, so likely to grow and distort as to necessitate frequent easing and adjustment.

The governor controls two valves, the first called the "Primary" admitting steam to the first group of nozzles. With further demand for load, the "Secondary" valve opens, admitting steam to additional groups of nozzles. It will be seen that the steam passes through these valves in series —*i.e.*, all the steam admitted to the turbine passes through the Primary valve. Therefore, so far as the safety of the machine is concerned, the Primary is the only valve which needs to be maintained steam tight. The valves are operated by means of an hydraulic cylinder in which oil pressure is used, controlled by a relay and floating lever of well known form. An innovation which exists here, however, is the result of experience with steam relays used on the older machines, viz., providing an oscillation of all the governor parts so that they are always in motion and hence ready to assume a new position without the friction of rest having to be overcome. Hydraulic relays of this type, as generally constructed, are provided without any lap, which is a little difficult of actual attainment. Should any lap exist, either positive or negative, the valve position will not be affected by a slight change of position of the governor, which generally results in a synchronous hunt. In this case, the relay is provided with ample lap and an oscillation is introduced in the governor mechanism which reciprocates the relay, uncovering the ports at each oscillation and giving a slight motion also to the piston and valves. This is not sufficient, however, to cause

any disturbance to the steam flow, as was the case with the old steam relay, the linkage, governor, etc., being kept in motion, eliminating the friction of rest. The effect of the movement of the governor weights is to change the plane of oscillation of the relay and the main piston. The latter will respond to the most minute change in the position of the governor weights.

Between the governor controlled relay and the piston is an additional relay which is operated by a small differential piston controlled by the automatic stop governor. The descent of this piston admits full oil pressure to the under side of the main piston, exhausting the upper side, and so closing the main valves irrespective of the position of the governor controlled relay.

Oil Pump.—The method of furnishing oil for operating this mechanism is to provide an oil pump driven by the turbine, capable of pumping to approximately 50 pounds pressure. Oil having passed through the relay mechanism, is then led to the bearings. An ordinary loaded relief valve is provided, permitting the oil delivered by the pump, which is not taken by the governor mechanism, to go to the bearings, the oil pump being proportioned to suit the requirements of the bearings, which is in excess of the requirements of the governor control mechanism.

Automatic Throttle Valve.—The throttle valve of a large steam turbine unit is an important detail, and the design employed on these large machines is illustrated in Fig. 18. It used to be considered good practice to employ an automatic throttle, which would be entirely separate and apart from the main throttle. This has been abandoned in favor of combining the two valves in one. The combination type compels the valve to be operated every time the machine is stopped or started, instead of only when the automatic features are used. Being the main throttle valve, it is more likely to be tight when required in an emergency. The design of valve here illustrated shows an external screw. The valve is forced shut by means of a powerful spring, and the violence of its closing may be regulated by an oil dashpot immediately below the spring. Valve seats are of Monel metal, which careful

experiments have shown best resists the cutting action of the steam, should there be a slight leakage. The valve closes automatically by the operation of a differential piston shown to the right of the illustration.

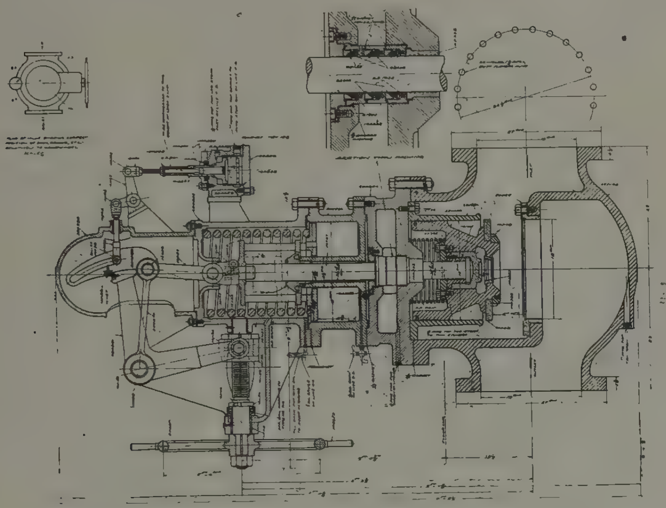


Fig. 18.

Automatic Stop Governor.—The automatic stop governor has not been subjected to change. It is entirely independent of the main governor and is secured directly to the turbine shaft. This is shown in Fig. 19. It comprises only an eccentric weight passing diametrically across the shaft, the centrifugal force of which is resisted by a spring. The spring is arranged so that its resistance to the movement of the weight increases less rapidly than the centrifugal force, so that the device once started, will have an accumulating force on the weight. The effect of the movement of the weight is to trip the trigger shown in the illustration, which relieves the pressure on a system of piping. Normally, this system of piping is connected to the differential piston of the automatic throttle, and that previously described in connection with the main governor controlled valves. It is frequently called upon to do other things, such as operating vacuum breakers, etc.

It is to be regretted that at this time there are no

authentic tests available on these large machines. However, many observations have been made by means of Lea Recorders, and it is indicated that the steam consumption of the smaller 60-cycle machines at 12,000 K.W. load is 12.25 pounds per K.W. hour, although in one instance,

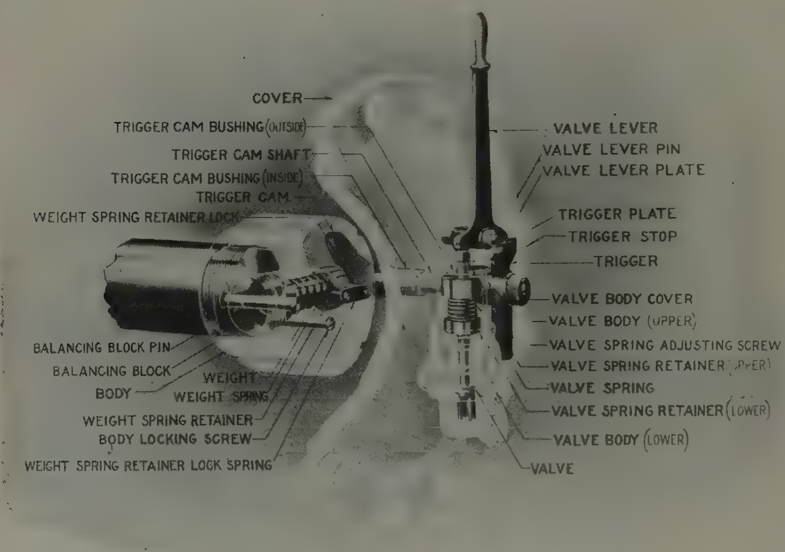


FIG. 19.

tests made with steam flow meters have shown 11.7 pounds, with 140° superheat. Similar observations on the larger 25-cycle machines indicate a steam consumption of approximately 12.0 pounds per K.W. hour. All of the foregoing with the one exception are with 200 pounds pressure, 100° F. superheat, and 29-inch vacuum.

THE INTERBOROUGH 30,000 K.W. TURBINES.

During the latter part of 1913, a contract was entered into with the Interborough Rapid Transit Co., of New York, for three 30,000 K.W. turbines. This has been regarded as a very important contract, the machines demanding the very highest economy. The machines will be operated in a plant along with a large number of units,

and will for the greater part of the time operate at their most efficient load, viz., 25,000 K.W. Hence a very small real gain in steam consumption warrants considerable capitalization. In the case of these machines, assuming that they are operating three-fourths of the time and that 1,000 pounds of steam are worth 12 cents, taking 6 per cent. interest and a fifteen-year life, one-tenth of a pound of steam per K.W. hour represents a capitalization per machine of $19,000.

While these machines represent a distinct advance in the size of units, as well as an improvement in economy, these characteristics should be accompanied with assurance of increased reliability. It would be entirely possible to construct such machines with but a single cylinder, operating at either 1,500 or 750 R.P.M., the former involving high speed blading at 800 feet per second or thereabouts, necessitating high grade alloy steels. The latter design would involve the difficulty of an enormous structure. Either of these machines would be of the combination type comprising an impulse element followed by an appropriate number of reaction elements in the low pressure stages, the latter being arranged double flow. The highest degree of economy, however, as has been shown before, is not to be obtained with an impulse element as compared with reaction elements, providing the steam volumes, speed, etc., are appropriate for the best design of the reaction turbine. On account of the large size of these machines, the advantage of dividing the expansion into two separate elements, i. e., reverting to the practice of many years ago, is apparent. An innovation in the construction of these machines is to have each turbine element drive a separate generator, each turbine operating as a synchronous speed best adapted for the turbine design. The high pressure element is a single flow reaction turbine operating at 1,500 R.P.M. The low pressure element is double flow operating at 750 R.P.M. The general arrangement of these machines is shown in a reproduction of a wash drawing, Fig. 20.

The steam after leaving the high pressure cylinder, passes through a receiver-separator on its way to the low

pressure element, by means of which most of the moisture will be separated.

Fig. 20.

The governor control is on the high pressure element only. The generators will be permanently connected by cables so that the low pressure will run in parallel with the high pressure element, carrying all the load it may with the steam delivered to it by the high pressure element.

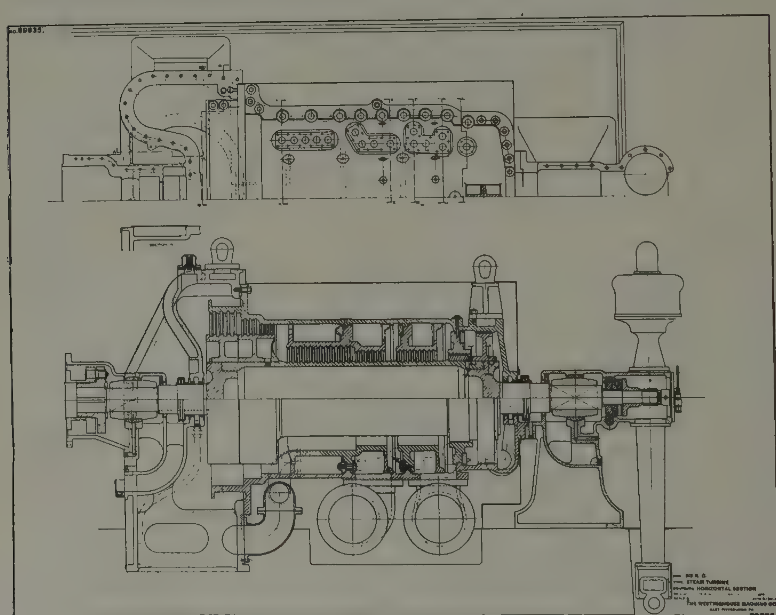


Fig. 21.

The detail designs of these machines are shown in Figs. 21 and 22, illustrating sections through the high pressure and

low pressure elements, respectively. The designs of details such as bearings, glands, governor mechanism, etc., are the same as have been described previously for other machines. To provide for high superheat, the high pressure cylinders will be made entirely of steel, and separate stationary steel blade carrying elements are provided. So far as concerns the high pressure unit, its construction is the same as that of many hundreds of machines which have been built, merely differing by reason of the very rugged blade proportions provided for non-condensing service. The low pressure element is

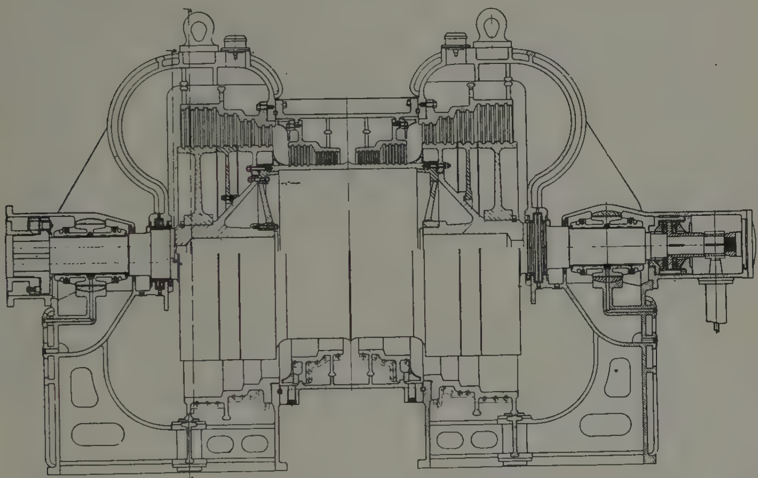


FIG. 22.

similar in construction to many low pressure turbines except that it is larger, the great size being brought about principally by the size of the exhaust chambers. The two exhaust outlets aggregate 190 square feet in area, providing for a steam velocity of 250 feet per second—the pressure of the steam corresponding to 29-inch vacuum. To simplify the casting, all stationary blades in the low pressure are provided with separate blade carrying elements. Attention is called to the ruggedness of the shaft construction, the calculated deflection of which is .013-inch. Some conception of the dimensions of the exhaust chambers of these machines may be gathered from Fig. 23. A point of interest from the

standpoint of the structure is in providing proper braces to insure rigidity of the exhaust chamber. Fig. 24 is a view looking into the exhaust outlet of one of these chambers and

Fig. 23.

here is shown some heavy ribbing, which if cast solid with the main casting would surely result in internal strains, even should the ribs not break in cooling. The ribs are cast as

here shown, disassociated at their intersection. After rough machining and annealing, each hub is bored out and a pin with a nut is pressed into place. The shoulders above and below the hub are suitably machined for shrink rings, in which manner the ribs are connected together, restoring them to their original strength and maintaining the casting without internal strains.

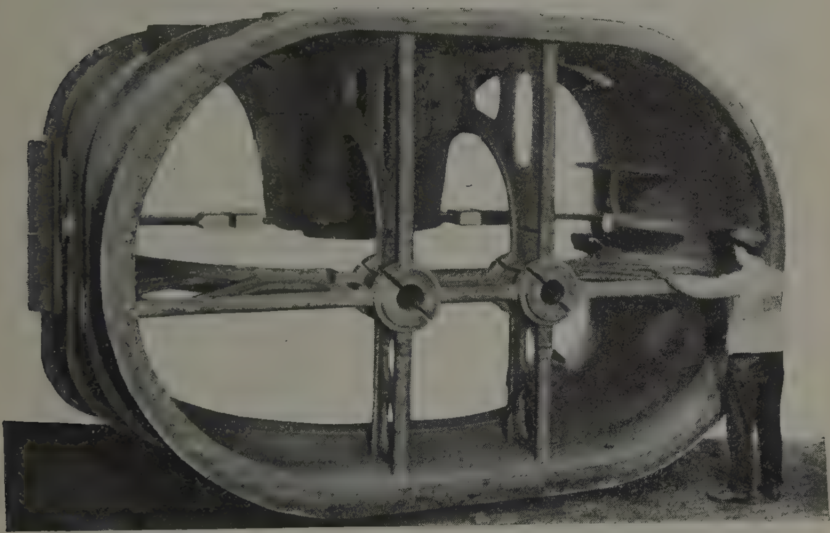


FIG. 24.

From what has been said regarding the losses in different types of turbine elements, when it is stated that the leakages in the reaction element vary in the high pressure from 4 per cent. to 2.5 per cent. and in the low pressure from 4 per cent. to less than 1 per cent. it is evident that the highest attainable economy is to be obtained with these machines. The blade dimensions in the high pressure element increase from 4-inch to 9-inch, and in the low pressure element, from 6-inch to 18-inch. The blade speeds involved are moderate, the mean speed of the low pressure blades 400 feet per second. The stresses involved in the revolving drums, etc., do not exceed 14,000 pounds at 20 per cent. overspeed.

It is perhaps improper to describe too much in detail, these machines in advance of the completion of their build-

ing. The author would perfer that this should come from his friend, Mr. Stott, after the turbines have been operated and tested. The steam consumption guarantee, however, at the point of best steam consumption, it might be added, is 11.27 pounds per K.W. hour, operating with 200 pounds pressure, 120° superheat and 29-inch vacuum. This represents 76 per cent. of the theoretical energy of the steam expanding between the above mentioned limits, being converted into electrical energy at the switchboard.

It might be asked here, why all turbines should not be built employing this cross-compound principle. Such machines are plainly more expensive than units having their expansion carried out in a single cylinder, not only because there are two complete and separate machines with the double number of bearings, etc., but also, having divided the machine up into two elements, one may employ turbine proportions conducive to higher economy, without being restricted by mechanical limitations. This greater expense can only be justified in the case of machines of large capacity, which will always operate with more or less constant load.

RECENT PROGRESS IN THE BUILDING OF LARGE STEAM TURBINES

Henry G. Stott

Superintendent, Motive Power, Interborough Rapid Transit Company, New York

Mr. Chairman and gentlemen, Mr. Hodgkinson has gone into the subject of the design of large turbines so fully that, rather anticipating that he would do so, I have confined my remarks to some comparisons with the results obtained from other types of prime movers.

There are just one or two points I would like to call attention to. First of all, the problem of the design of turbines used to be to get good castings. As superheat began to be used, it was found that iron castings would gradually change in their physical dimensions. Not only would they distort under sudden changes of temperature, but they would change their physical dimensions—actually grow. This rendered it practically impossible to use the cast iron. Therefore, in all the high pressure systems, such as the prime movers, where superheat was used, steel castings had to be used. The problem of getting good steel castings was another difficulty, one that has apparently been vanquished.

The next problem which arose was an entirely new one. It was really the condition of harmonics due to the vibration produced by steam in the blades. While many attempts have been made to overcome this by different methods of bracing and shrouding, it yet remains the one bugaboo left in the design of large steam turbines to overcome the multitude of vibrations which take place due to the one row of blades passing over another—moving blades passing the stationary ones.

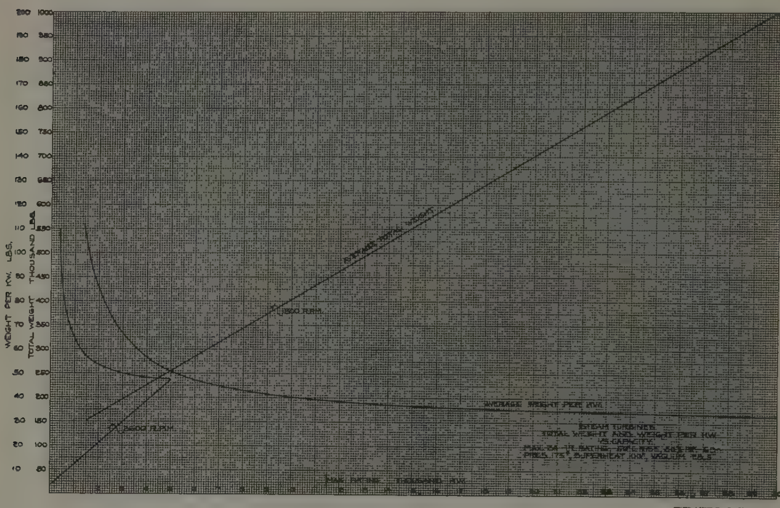


CHART I.

This is Chart I., showing the different sizes of turbines made by various manufacturers. You will observe that they start in with the small sizes, with a capacity of about 5,000 K. W. in rating, the weight per K. W. is about 50 lbs., and from there it gets down in the larger sizes, to a weight per K. W. of about 33 lbs. If you will retain those

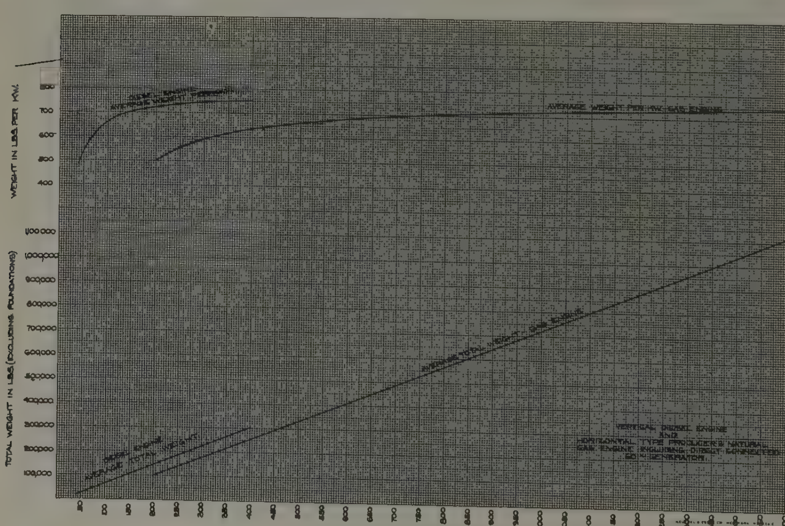


CHART II.

figures, from 50 lbs. to 33 lbs., in mind a moment, you can compare it with the next slide.

On Chart II. are shown the average weights per K. W. for gas engines and the Diesel type of engine. In the Diesel engine you will find the weight goes up to 750 lbs. per K. W. as compared to the 50 lbs. or 33 lbs. on the turbine. The gas engine runs along not very far from the Diesel engine, running 600 lbs. per K. W., or if you want to reduce it to horse power about 25 per cent. less.

Chart III. shows the average cost per K. W. for gas engines

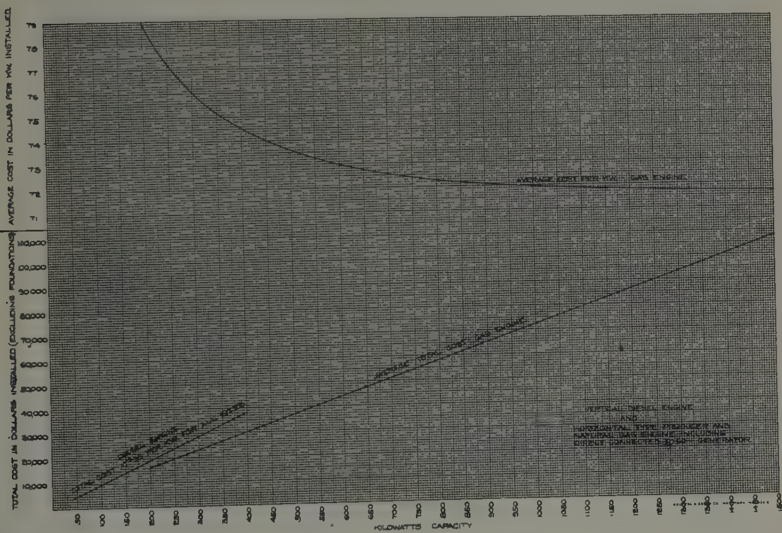


Chart III.

and also for the Diesel engine. We found, as near as we could get it, that the cost for the Diesel engine was approximately $95; that seems to be practically independent of the size, whereas the gas engine comes down to a total of about $73, or as low as $72. These were taken from the average of a great many figures.

Chart IV. shows the average thermal efficiency ratio of steam turbines running in various sizes from 2,000 K. W. up to 30,000 K. W. The upper curve shows the actual thermal efficiency,—the thermal efficiency being the ratio of the total heat supplied to the turbine, to the total equiv-

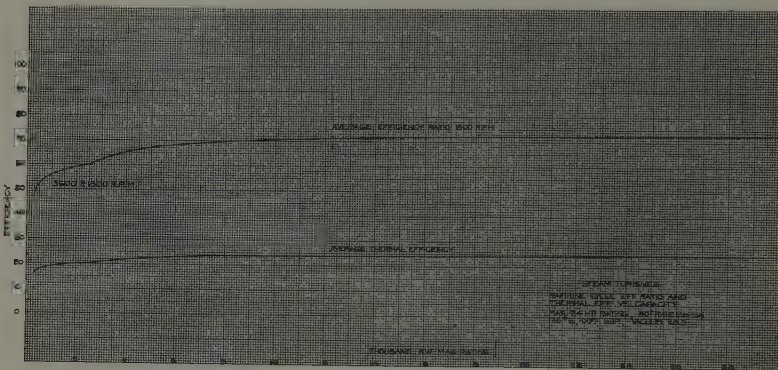


CHART IV.

alent heat given out,—the efficiency going up in the larger sizes about 25 per cent.

On Chart V. we have the thermal efficiency of various types of prime movers together. The thermal efficiency you will notice goes up to about 28 per cent. That is the most efficient type of prime mover we have at the present moment.

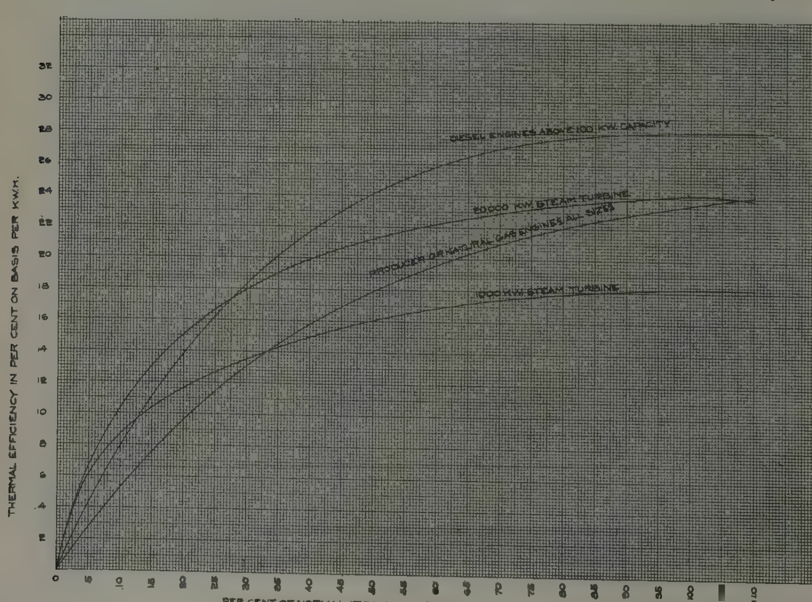


CHART V.

You will notice a remarkable thing in the next chart (Chart VI.), the large steam turbine has now reached the

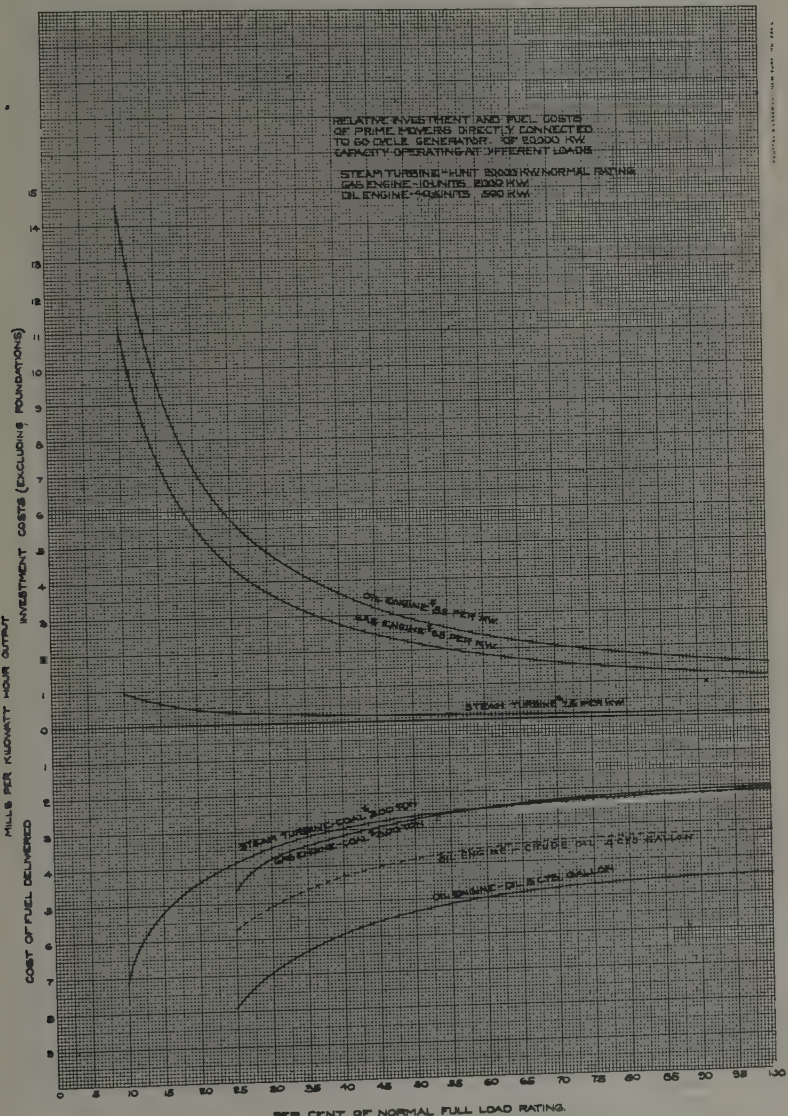


CHART VI.

same efficiency practically as the gas engine in all sizes, the efficiency of the gas engine being almost independent of size, within a very wide range. That is perhaps the most

remarkable development that has been brought to our attention in a great many years, and it was surprising to work over the figures and find that it came out in that way—that the steam turbine has now caught up with and is better than the gas engine. The small curve is a small steam curve which is put on for comparative purposes, showing the relation between the large and the small turbines.

This shows what is really the meat of the situation regarding prime movers. The upper curves show the fixed charges per K. W. for various types of prime movers. For example, we start at the top with the oil engine, the next one, gas engines, and the lowest curve of all is the steam turbine. Down below the line, we find the cost of fuel per K. W. hour, so you can take these two ordinates together, which give the total cost per hour, leaving out of account the labor. From that you will see something which is ignored in a great many cases, namely that the fixed charges on a given unit are often more important than the efficiency of that unit. For example, you will find the gas engine and steam turbine curves are practically overlapping one another. On the oil engine the price of oil has been taken at four cents a gallon. Of course, by reducing that to three cents a gallon, you get down to practically the same curve for the operating cost of fuel as you have for the steam turbine and the gas engine. But if you take the sum of these ordinates, above and below the line, which is the true cost of the power, you will find that in every case the steam turbine gives the least total cost. This, I think, is really the meat of the whole situation in regard to prime movers. We must take into consideration, not only the operating cost, but also the first cost, the fixed charges.

If you recall the relative weights, we found that the steam turbine—even small ones—were down to fifty pounds per K. W. in weight, whereas the corresponding sizes of gas engines were up to and over 700 lbs. That, of course, of itself accounts immediately for the difference in cost.

And the floor space occupied is also rather interesting. With the horizontal steam turbine we can get for one square foot of surface from 10 to 15 K. W. in capacity, whereas with

the gas or oil engine we get only 8 to 10 K. W. capacity per square foot. That also gives a very good relative idea of the sizes of the relative types of units. This curve here to which I have called your attention I think really contains the crux of the whole question of prime movers.

SOME RECENT DEVELOPMENTS IN BY-PRODUCT COKE OVENS

William H. Blauvelt

Consulting Engineer, Semet-Solvay Company, Syracuse, N. Y.

At the meeting of the Institute in New York a year ago the status of the by-product oven in America was most ably presented and the interest with which that paper was received encourages me to bring to your attention some of the latest developments in this industry, which is becoming of such importance to the iron and steel manufacturer. In 1913 the tonnage of by-product coke amounted to 12,714,700 tons, or over 27 per cent. of the total coke produced in the country. This is an increase of about 1,600,000 tons over 1912, and it is probably safe to prophesy that by the close of the current year the production will be at the rate of 14,000,000 tons. Compared with 1910, this means a growth of 100 per cent. for four years.

Conserving our National Resources.

From the United States Geological Survey reports it appears that the average value of the coke and by-products obtained per by-product oven in 1912 was $11,265, as compared with $1,019, as the average yield per bee-hive oven. The total value of the by-products recovered was over $16,000,000. If the by-products had been recovered from the coal used in making coke in bee-hive ovens, they would have been worth approximately $80,000,000—at the prices ruling in that year. The average yield of coke from by-product ovens was 75.3 per cent. and in bee-hive ovens 64.7 per cent., a difference in favor of retort ovens of 10.6 points, or 16.4 per cent. If this difference had been added to the production of bee-hive coke it would have added to the wealth of the country 5,390,000 tons of coke if the same coals had been coked in by-product ovens, in addition to the above value of the by-products. This loss is equivalent to the absolute

destruction of about 6,800,000 tons of our coal supply during the year. I have given these figures as suggestive of the importance of the by-product oven in the conservation of our natural resources. In this connection it is interesting to note that recent work in some by-product oven plants is showing conclusively that the high volatile coals of the Connellsville and Klondike districts make by-product coke quite equal to the best coke that can be made in bee-hive ovens from the same coals.

The map which I have thrown on the screen shows the distribution of the by-product coke plants in the

★ Semet-Solvay ⊙ Koppers ✚ Didier
▲ Otto-Hoffmann ✖ Rothberg ☾ Klönne

United States. There are 42 of these plants. The map shows that in almost every case the by-product ovens are

located at the point of consumption rather than at the coal mines, as distinguished from the almost universal practice with regard to bee-hive plants. In the five coke-producing states of the South the percentage of by-product coke is much larger than in the country as a whole. With the completion of present construction nearly half of the coke made in the South will be by-product coke. This point is worthy of consideration in connection with the work the Southern States are doing in the conservation of their resources.

The principal increase in by-product coke production in 1913 was in Alabama, where the gain was over 50 per cent. in the year. The increase in Pennsylvania was nearly one-third the production in 1913, being 2,628,680 tons.

One of the most notable improvements which has been made in the industry since its introduction into this country is the increase in output per oven unit and per man employed. When the first ovens were brought over from Europe they had a capacity of 4.4 tons of coal per day, and one crew of men was capable of handling about 25 ovens. This gave a capacity of 110 tons of coal per day with a unit crew. To-day the most modern ovens have a capacity of 20 tons of coal per day, and improved organization and modern machinery permit practically the same crew to handle from 50 to 60 of these ovens, thereby coking from 1,000 to 1,200 tons, instead of the original 110 tons. I know of none of the other metallurgical industries which has shown the same growth in tonnage efficiency in the same time. This is a conservation of labor well worth consideration along with the conservation of our coal supply. Progress in this respect has been distinctly greater in America than in Europe.

Waste Heat Ovens.

The by-product oven has been developed along two lines: the waste heat oven, and the oven recovering the maximum amount of surplus gas. The former is the simpler type. It is ordinarily installed in places where the gas has comparatively little value. As is well known, in the carbonization of coal in a retort oven a portion of the gas produced is used for heating the ovens while the remainder is available for

other uses. The waste heat oven is not designed to obtain the greatest possible quantity of surplus gas, and the products of combustion going off at a high temperature are utilized for raising steam. This practice is comparable with that employed in those bee-hive oven plants where the tunnel-head gases are collected and led under boilers, and to the non-regenerative heating furnace with boilers for utilizing the waste heat.

With the growing use of machinery for the storage and preparation of coal and for the preparation of coke, and the substitution of machinery for hand labor in other parts of the process, the requirements for power have grown materially, so that the amount of power required for a modern coke oven plant is very considerable. There are many cases where the most economic results are obtained by a plant so designed that there is just enough heat in the waste gases to supply the steam required for the operation of the plant, leaving the remainder of the gas available for sale.

A boiler plant properly designed for waste heat, with its accompanying economizers for preheating the feed water, is the most economical apparatus for utilizing heat in an industrial plant; that is, such a boiler plant will deliver the gases to the chimney, or to the exhaust fan which often re-

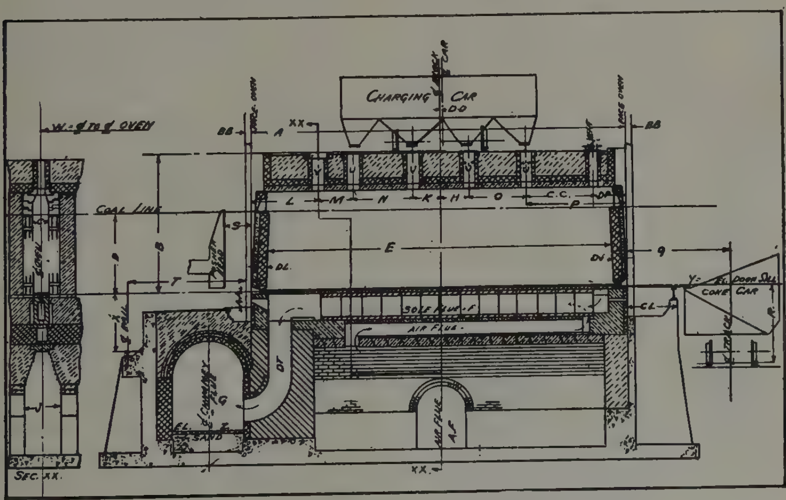


FIG. 2.—Simple form of recuperator oven.

places the chimney, at the lowest possible temperature consistent with commercial results. Such a design permits a very simple type of oven, with low first cost and low cost of operation. In the type of oven with which I am most familiar, the Semet-Solvay oven, these principles have been thoroughly developed in what is called the recuperator oven, and under the conditions described above very satisfactory results have been obtained. I will throw on the screen a slide (Figure 2) showing the arrangement adopted in the construction of this oven.

The gases are burned in the combustion flues shown, and then passed to the sole flue beneath the oven and out through the chimney flue to the boiler plant. The air for combustion passes first under the sole flue and then through the narrow flues on each side, where it comes into intimate contact with the heated brickwork; thence upward to the heating flues, where it meets the gas. By a proper proportioning of these parts enough heat is abstracted by the air from the waste gases so that the highest temperatures may be produced in the combustion flues, and at the same time sufficient heat remains in the waste gases to produce all the steam required for the operation of the plant, without any expense for fuel or for labor in firing. By this system something over 40 per cent.

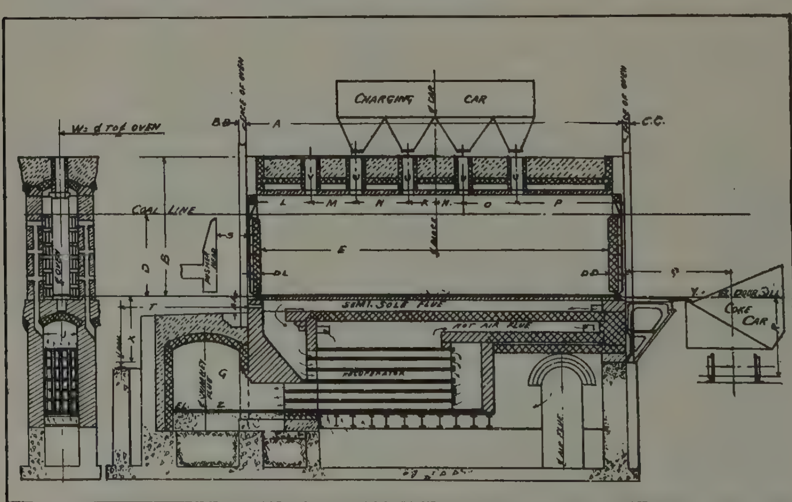


FIG. 3.—Oven with more complete recuperator.

of the gas is available as surplus. This system requires no attention from the operators except the regulation of the air at the burners on the one hand, and the maintenance of proper water supply to the boilers on the other. This method of heating the air is called "recuperation" to distinguish it from the familiar form of regenerator common to most high temperature furnaces.

The next slide (Figure 3) shows a more efficient form of recuperator, modelled somewhat after the recuperative glass furnaces, for example, which are successfully used in Europe. In this oven the hot gases pass through the recuperator flues, making two passes on their way to the chimney flue, and the air rises through the small vertical flues arranged in the special brick used to build up the recuperator. It is manifest that there are many cases where this type of oven, with its low cost of construction and simplicity of operation, has important advantages.

Regenerative Ovens.

In plants where there is a demand for all of the available surplus gas at a good price, it is, of course, desirable that the oven should be designed to use the smallest amount of gas for fuel, even though the chimney losses are greater, and the cost of producing steam for the plant is increased. It is clear that there is a dividing line which must determine the selection of the best type of oven for any given installation, and that all the factors entering into the undertaking must be given due weight before either type is adopted.

The next slide (Figure 4) shows an oven designed to operate with the smallest amount of fuel, and at the same time maintain, as far as possible, simplicity of construction and operation. In this design regenerators are substituted for the recuperative system, one pair of regenerators for each oven, with the two chimney flues arranged between them. The whole construction of the oven and regenerator is located between the two vertical walls peculiar to this type of oven. These walls extend from the concrete foundation straight through to the top of the oven. The operation of the regenerators is, in general, similar to that of an open-hearth

furnace, except that an entire block of 60 or more ovens is reversed at one operation, as will be described later. The air is usually blown in by a fan located beyond the reversing damper and is distributed under the block through one chimney flue. It enters at the bottom of the regenerator, rises and passes through the flue system, meeting the gas at the several burners in the combustion flues. On reversal, the air enters the other regenerator, rises through the air

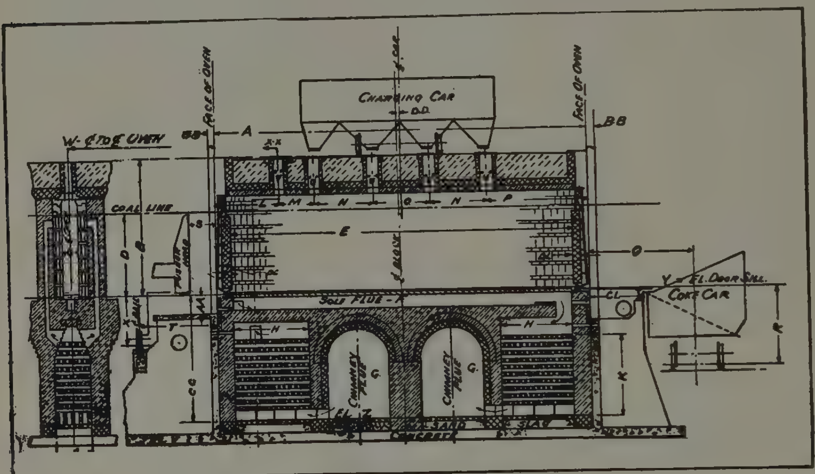


FIG. 4.—Modern type of regenerator oven.

flue, shown in dotted lines, and descends through the horizontal combustion flues, meeting the gas as before. The products of combustion pass out through the other regenerator to the reversing damper and stack in the usual manner. By this system the entire series of combustion flues are swept by all of the air required for combustion, so that hot spots are prevented and a very uniform temperature is maintained throughout.

PROBLEMS IN OVEN HEATING.

Any one familiar with the use of the high temperatures required in metallurgical work will realize the difficulties connected with the proper heating of a by-product oven. The walls of the chamber are, say, 36 feet long and about 12 feet high. Every portion of both of these chamber walls must be

heated to a high temperature, and the temperature must be uniform in all parts, excepting that perhaps the upper part may be somewhat cooler. Any inability to control the temperature at any portion of this surface, about 430 square feet, means the production of imperfect coke, delay in the operation, or injury to the brick work. The method used in controlling the heat over this surface is shown in the next slide, (Figure 5), in diagrammatic form. The air raised by the regenerators to a temperature of about 1000° to 1100° C. travels through the flue system, as above described. At the ends of the flues are shown gas burners, consisting of simple pipes, which admit the gas as shown. When the air is traveling

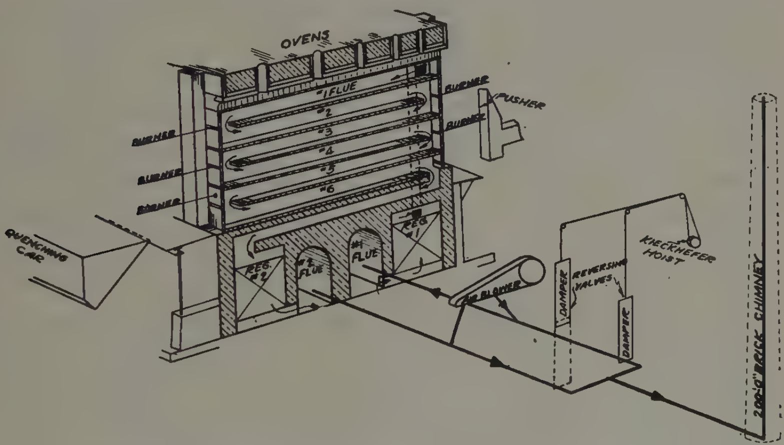


FIG. 5.—Showing method of controlling the heating to secure uniformity.

downward through the system it flows through the first flue until it reaches the first gas burner shown at the left. The stream of gas is deflected downward by the air current and burns in the air as it travels through the flue. At the end of the second flue the air meets another stream of gas, which also is deflected downward and heats the third flue, and so on, until the gas from the last burner consumes the last of the oxygen.

When the air current is traveling upward the streams of gas are deflected upward, so that the entire combustion system is reversed at the usual half-hour periods by the manipulation of only one reversing damper for the entire block of

ovens. A proper adjustment of the relative amount of gas delivered by each of the burner pipes maintains just the right relation between the heats in the different parts of the system, with the minimum attention. This method insures the most even distribution of heats throughout the whole heating system. It seems clear also that in the practice of passing the entire volume of air required for the combustion through the entire flue system there is a gain in efficiency of transfer of heat from the hot gases to the oven walls, as compared with the older methods of heating.

Theory of Oven Heating.

There has been some dicussion as to whether the heating of a by-product oven is effected by radiant heat or by convection and conduction, but I believe that the arguments are distinctly in favor of the latter theory. Under the conditions which exist in a coke oven the brick wall, at working temperatures, is a good conductor of heat. This is illustrated by the fact that an increase of the thickness of this wall from 2½ inches to 4½ inches does not demand in practice a higher temperature in the flues to produce the same result in the coking chamber. The flame as burned in the oven flues is only slightly luminous, and it has been shown by good authority that the radiation from a non-luminous flame is only about one-third of that from a luminous flame. Moreover, since radiant heat is transferred in accordance with the difference between the fourth powers of the temperatures of the radiant and receiving bodies, while heat is transferred by conduction proportionately to the first power of the difference in temperatures, it would seem clear that under the conditions we are considering, at least a large portion of the heat transferred from the hot gases to the flue walls must be by convection and conduction, and the system which uses this latter method is the more efficient.

In a system of heating flues where the layers of gases lying next to the walls are practically stationary, or moving slowly, it has been shown by experiment that these layers of quiet gases form an effective non-conductor which offers a greater obstacle to transfer of heat than the degree of conductivity

of the wall itself. When the flow of gases is sufficiently rapid to sweep away these quiet layers, the hot gases are permitted to come in direct contact with the walls and transfer their heat to the substance of the wall according to the first power of the difference in temperatures, and the efficiency of the transfer is proportionately good. The comparative rapidity of flow of the gases during their combustion also has the practical value of distributing the heat and preventing injury to the brickwork, avoiding thereby the dangerous condition which arises in an operation where temperatures are generated approaching the melting point of the refractory material.

Turning to the diagram on the screen it will be seen that each burner is directly under the hand of the man in charge of the heats as he walks in front of the ovens, and each flue may be inspected by a glance, by the removal of a plug from a peep-hole. The importance of convenient access both to the control of the gas supply and to the inspection of the heating flues in a block of by-product ovens cannot be stated too strongly. With a given coal, the quality of the coke produced depends very much upon the maintenance of the proper temperature in the oven, not only as a whole, but in every part, since nothing injures the quality of the coke more effectively than inequalities in the heat in different parts of the chamber, so that certain portions of the charge are over-coked while the cooler spots are being finished. In an industrial plant it is essential that any important operation shall be done conveniently and in comfort to the operator, otherwise one may be sure that it will be done badly except under the closest supervision. Given good construction and simplicity of parts, the oven which permits the most convenient and accurate control of the heats is the best oven.

SOME RECENT DEVELOPMENTS IN BY-PRODUCT COKE OVENS

Carl A. Meissner

Chairman, Coke Committee, United States Steel Corporation, New York.

The figures given in Mr. Blauvelt's very interesting paper show in a striking manner to how great an extent our national coal resources, and the valuable by-products derived therefrom, could be conserved by the more extensive use of the by-product as against the bee-hive coke oven in the manufacture of coke. He also describes the development made by his company in the construction of by-product coke ovens in increasing their capacity and efficiency.

Mr. Blauvelt shows clearly how much has still to be done in this country in order to replace the bee-hive ovens by the by-product ovens. The main reason for this is claimed to be the high initial cost of constructing a by-product oven plant as against a bee-hive oven plant. I say "claimed to be," because when we consider all the costs—the conservation of the coal, larger coke yields, the recovery of the gas, tar, sulphate of ammonia, benzol, etc., in fact, all factors connected with the question of manufacturing coke from coal—it is not possible to present any figures that will not show a much larger return on the original investment from a by-product coke oven installation as against a bee-hive coke oven installation for coking the coal taken from a given area of coal lands. This is the ultimate crux of the whole situation from a manufacturer's standpoint.

The advantages of better coking control, more uniform quality of coke, ability to collect and mix at one plant various coals, to improve blast-furnace operations, also lessen the coke consumption and reduce the whole cost of making pig iron as well as improve its quality for making steel are all points that have to be taken into consideration.

Mr. Blauvelt refers to the gradual increase in capacity

of ovens, which is governed largely by their dimensions and by the coking time. I am satisfied that we will be able to increase this capacity slightly with every new plant that we may build until the final limits, which will be governed by practice and experience, are reached. Great care must be exercised in doing this. I know of several cases where attempts were made to "jump" to greater dimensions with very unsatisfactory results.

As to the number of ovens to a battery and the number of batteries to a plant, this is again a matter for careful study and consideration, and I would like to ask Mr. Blauvelt what he considers from his experience to be the limit in such units from the operative standpoint. We have at Gary, Indiana, 560 ovens and at Joliet, Illinois, 280 ovens, and our experience has been that the operating cost per ton of coke at these two plants is practically the same. We feel that it would not be wise to place more than up to 100 ovens of American silica brick construction in a battery nor install more than 600 ovens in a plant unit. The operative supervision becomes more difficult unless additional department heads are employed, which means increased cost, and where coke has to be "made right" in order to give the best results in a blast furnace, this operative supervision is a factor of prime importance.

The most important question that has probably delayed more serious consideration of by-product coke oven installations and prevented greater progress in this direction, has been the one of whether high volatile coals can be coked in by-product ovens so as to give as good a blast-furnace coke as many of them do in bee-hive ovens. This refers particularly to the great Connellsville and Klondike coal regions, though it also affects many other districts having high volatile coals heretofore not considered fit for coking even in bee-hive ovens. Mr. Blauvelt refers to his successful experience with the use of high volatile coals in by-product ovens, and all of our experience in this direction shows that many of these high volatile coals can be coked to the extent of 100 per cent., so as to give a good blast-furnace coke, while in other cases suitable coke is made by the admixture

of 10 to 35 per cent. of low volatile coals. Even those coals which have been considered by many as not being at present available for coking purposes—such as certain sections of the Pittsburgh seam, and those of a great many other coal districts—have been and are being used to make a satisfactory blast-furnace coke by being mixed with larger quantities of low volatile coals, up to 60 and 80 per cent of the latter being used.

There can be no further question in my mind that the present types of by-product coke ovens have solved the problem of ultimately being able to utilize for coking purposes in a greater or less degree almost any bituminous coal found in this country. Even anthracite coals are mixed in small proportions with some of the high volatile coals in Germany and have been found to make a more satisfactory coke than some of these high volatile coals when coked at 100 per cent. All this it is utterly impossible to carry out in the wasteful bee-hive oven.

In view of all the above, the point of keen interest is the type or system of by-product oven which is best suited for accomplishing this.

Mr. Blauvelt very clearly points out what the requirements of the horizontal type of oven are for this purpose, and he shows that simplicity and perfection of uniform heating are the two main requisites.

The new Semet-Solvay horizontal flue regenerative oven described by him is the latest type of by-product oven constructed to meet the conditions in this country. It naturally differs materially from the latest type of vertical flue oven now in successful operation in the United States. The oven described by Mr. Blauvelt represents the successive and progressive steps made by the Semet-Solvay Company in strength, simplicity and effort for uniform temperature.

Much has been said in favor of simplicity of recuperation as against regeneration for the combustion of the gas in the flues, also of continuous heating versus reversing; but all told, all modern types have finally found it to be more economical and efficient to use regeneration in place of re-

cuperation, except in certain isolated cases, as pointed out by Mr. Blauvelt. Unless great care is taken in design, it is almost impossible to prevent short-circuiting or leakage of gas and air in recuperative chambers or flues and this is not only wasteful, but impairs to a certain extent the efficiency and the control of combustion.

The strength of construction in this latest type of Semet-Solvay oven is a noteworthy feature of great importance, for strength of oven and flue walls is imperative in our modern coke oven practice of fast driving necessitated by short coking time. The simplicity of control of gas and air and the ready supervision of the combustion in the flues by means of peep-holes are factors that will appeal to all coke oven operators.

As to coking time, I regret we have no definite data from Mr. Blauvelt, for this is a point of great importance to us. We have found as a rule that the shorter coking time gives the best blast-furnace coke and that there must be no delay in pushing the coke out of the oven after it is coked. What the actual length of coking time for various coals alone or in mixture is, has to be determined by actual trial; so far we find that there is no great difference in coking time in the type of oven with which I am most familiar, whether we use high or low volatile coals. It may be found advisable to increase the coking time somewhat when using all high volatile coals, but the difference between this and low volatile mixtures does not in our present experience exceed say two hours on the average.

In view of its ability to obtain high and uniform coking temperatures, I can see no reason why the new Semet-Solvay coke oven should not be able to make coke in practically the same time as that of any other system.

All in all, this latest development is of keen interest to us as it is the purpose of the company with which I am connected, the United States Steel Corporation, to adopt always the latest and most approved type of by-product coke oven, being in no sense whatever tied down to any one system by preference, prejudice or any other reason.

EVENING SESSION

The Annual Dinner was held in the Grand Ballroom of the Waldorf-Astoria, Judge Gary, President of the Institute, acted as toastmaster.

When the dinner had been partaken of, Judge Gary called for order and said:

Gentlemen, I congratulate you on being members of the American Iron and Steel Institute, and I congratulate the American Iron and Steel Institute on having such as you included in its membership. I have had the pleasure of attending a great many different banquets given in this hall, and I have never before seen a more splendid audience—men with more ability, perseverance and success, which make them a potential factor in the affairs of this country. And you will continue to rise to your opportunities and to render service which shall be of lasting benefit to the people of this country.

I now introduce Dr. Darlington, who has twenty minutes in which to speak of the welfare work of the Institute up to the present time. Dr. Darlington.

PRESENT SCOPE OF WELFARE WORK IN THE IRON AND STEEL INDUSTRY

THOMAS DARLINGTON, C.E., M.D.

Secretary Welfare Committee, American Iron and Steel Institute.

On the banks of the Rappahannock after a day of battle, just as the sun was setting and the guns had ceased firing, a Federal band marched down to the stream and played "Dixie." When they finished the applause came from the opposite bank. Again they played. This time "Yankee Doodle" was the strain; this time the applause came from the Federals. Once more they played.

The sad slow stream its noiseless flood
  Poured o'er the glistening pebbles;
All silent now the Yankees stood,
  All silent stood the rebels.

No unresponsive souls had heard
  That plaintive note appealing,
So deeply "Home, Sweet Home" had stirred
  The hidden founts of feeling.

Before all arose a vision of that vine-clad cottage amid the trees, where waited that mother, that wife, or that sweetheart left behind—and in "Home, Sweet Home" they were all united. Here to-night we sing a song, a song of humanity, a song in which all can unite.

The struggles of life are not all found upon the battle-field. You are gathered here to-day, not in competition, not for aggrandizement, nor yet for amusement, but for the purpose of gaining from each other suggestions of better methods of manufacture, more wisdom in the conduct of business and greater skill in promoting the interests of humanity. It is indeed a great pleasure to view this body of men of intelligence and influence serving the world with

ideas that are of so much value and of so much interest to all mankind.

Well have the members earned the right to congratulate themselves upon their accomplishments and the great improvements made. If I were to confine my remarks to the commemoration of the achievements of a single company or to one line of work I could well fill the time. But that which appeals to me as most worthy of mention is that spirit which makes the efforts of a part the achievement of the whole, which regards the work of each member as contributing to the honor and glory of all. The greatest honor is due to those in whom the thought of individual credit is cheerfully waived in the service of universal good.

Present Scope of Welfare Work in the Iron and Steel Industry.

Among the general subjects now covered by welfare work in the American iron and steel industry are the following:

Prevention of Accidents.

Drinking water supplies
Washing facilities
Laundries
Lockers
Toilet arrangements
Drainage and sewage disposal
Disposition of garbage and rubbish
Care of stables and animals
Heating work places in winter
Cooling work places in summer
Ventilation
Overcrowding
Dust, gases and fumes
Lighting
First aid
Hospitals
Trained nurses and social workers
Physical examination of employees
Lunch buckets and lunch rooms
Commissaries (bread, meat)
Milk supplies
Flies, mosquitoes and vermin
Clean mills and yards
Housing
Gardens
Rest and recreation

Education
Relief funds
Compensation
Insurance
Pensions
Saving and investing

The results accomplished and the benefits derived from welfare work must be judged of largely by our reasons for doing it. Owing to a lack of statistics for comparison the ultimate results of such welfare work cannot yet be shown.

Later on, when statistics have been recorded, results can be stated in more definite terms; but even then the highest results cannot be tabulated or even expressed in words. Nevertheless by a short review of some of the work we may realize to a certain extent what these benefits are.

Water.

Much has been done toward obtaining wholesome drinking water supplies. Many supplies have been examined not only by survey of their source, but also bacteriologically and chemically. As the result of such examination many supplies have been abandoned, while other supplies, such as springs, have been walled up to prevent surface pollution, or have been removed, while still others have been filtered or purified. It requires no investigation to show the good resulting from such work. Scientific research has conclusively proven that polluted water supplies may cause disease, such as typhoid, dysentery or diarrhœa. The abandonment of such polluted supplies has made healthier conditions.

Besides being purified, some of the mill supplies have been cooled by ammonia machines or brine solutions so that icing the water has been done away with. Where this has been done, cramps have been entirely eliminated.

Moreover, in the process of purification, of removal of turbidity, proper cooling and the use of drinking fountains, the supply is made more attractive. Therefore more water will be drunk. For physiological reasons this favorably affects both health and efficiency. Water is a natural con-

stituent of the body and is to be considered as a food, though not in the sense that it liberates energy. It affects secretion and excretion and the activity of the various organs. It aids in the absorption of food and carries away waste. It diminishes fatigue. It regulates body temperature and acts as a distributor of heat. And there seems to be no question but that the drinking of water lessens alcoholism. On the other hand, water may carry lead in solution, and so poison. Drinking cups used in common carry disease.

Much has been done in the installation of basins and showers and in the erection of dry houses. In many places these have had the widest use, a large percentage of the employees bathing daily. Here again we cannot adequately estimate the good derived. But we do know that such facilities enhance one's self-respect and the respect of others.

The opportunity to wash before going home makes the work of the home less burdensome, and cleanliness of the hands is of especial importance because hands carry disease.

Shower baths affect the circulation of the blood, not only in the skin but in the whole body. They produce a redistribution of the blood in the body and for the time being there is an actual change in the blood itself. Cold showers increase capacity for muscular work. Showers eliminate more rapidly the products of waste and so constitute one of the methods of relieving fatigue. A shower bath removes the waste products from the skin and makes one less liable to feel a change in temperature. It reduces the heat of the body, especially on humid days when the body temperature may rise above normal.

Incidentally I would mention that the roller towel has been abandoned in the majority of plants.

Many new toilets of modern construction have been built and hundreds of old privies have been abolished. Especial care has been given to the exclusion of flies and the prevention of pollution of the soil. There have been many improvements in the disposal of collection from pan privies, especially by incineration or in septic tanks.

Much pollution of streams has been done away with.

Thousands of dollars have been spent for drainage, particularly of back alleys and streets. This drainage has had a very beneficial effect in the prevention of the breeding of mosquitoes and prevention of malaria.

Better methods of collection of garbage are constantly being installed with short periods of collection. Much has been done in the way of education of employees in the use of garbage cans and the necessity of keeping the contents

covered. This prevents the carrying of bacteria by flies from the can to the table.

In the prevention of the breeding of flies, much has been done, especially in mining camps and villages by the prompt removal of manure and making the stables more sanitary. Education by means of circulars explaining the dangers of flies as carriers of disease has accomplished much.

The cooling of work places in summer is now being considered in many plants and much is being done to make heated work places more comfortable, thus preventing heat stroke.

Making stables sanitary.

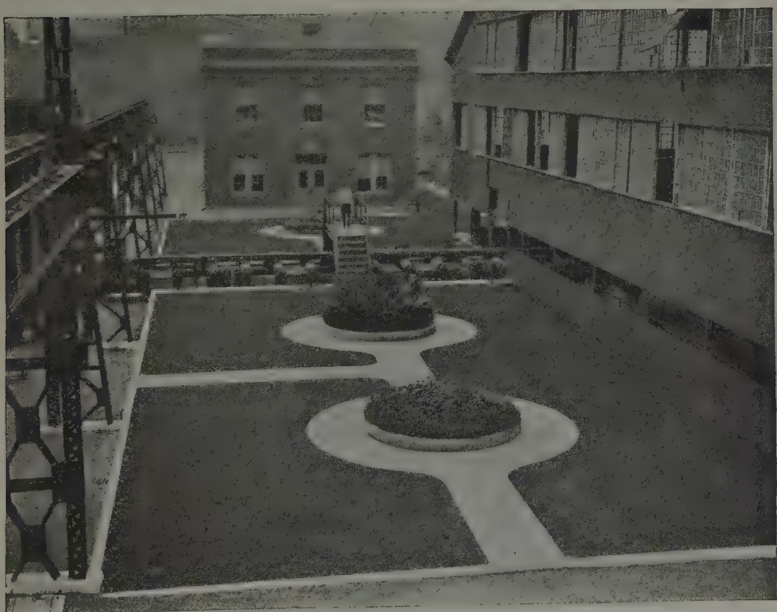
Thirty years ago, according to English statistics, nearly all who breathed dust from grinding steel and stone, died sooner or later from tuberculosis. Such dust has been entirely eliminated from certain mills in the industry.

Air conditions have been much improved by the elimination of the hydro-carbon series and other gases produced by open fires where combustion is incomplete. These gases are now carried to the outside of the building.

Much improvement has been made in the heating of plants in winter by fresh air brought from the outside, filtered, warmed and distributed to the various parts of the building to be heated. This insures a good supply of air free from dust and gases.

How often have men fallen upon fruit skins or the remains of luncheon thrown upon the ground, or have stepped upon a plank on which a rusted nail has been sticking out. Perhaps more has been done in the making of clean yards than in any other direction. It is also to be noted that the psychological effect of pleasant and clean surroundings has an excellent effect upon the workmen. Beauty and order are persuasive everywhere and few people can resist them.

Progress in first aid has been so wonderful that the steel



Instruction in First Aid.

industry is now leading the world in this line of welfare work. The results of such work have never been better shown than in the paper read before the Institute one year ago by the surgeon of one of the largest companies. The reduction of septic cases from 50 per cent. to $\frac{1}{10}$ of 1 per cent. speaks volumes. Nowhere else in the world has such provision been made for the care of employees who are injured. The emergency hospitals which have been provided near mine and mill stand to-day as examples for the whole world. They have materially aided in reducing human suffering. Many lives have been saved, much has been done to prevent fatal termination by prompt care and by the knowledge on the part of the injured workman that such care is the best that can be obtained.

Emergency Hospital 396 feet underground.

A rest farm for the wives of employees who are in poor health has been established. This farm is under the care of a physician and nurse.

The support given settlement houses and the employment of trained nurses have done much toward keeping the companies in sympathy with the employees and replacing despondency with sunshine and gladness. These trained nurses have given their attention to the women and children, particularly babies. Their duties include the weekly weighing of babies, teaching mothers how to dress and undress them, how to modify their milk, the guidance of expectant mothers and nursing them during confinement, the care of children, medical school inspection and other things too numerous to mention. At many of these settlement houses and in other houses set aside for the education of mothers they have been taught to make rag carpets, the boys have been taught carpentry, classes of girls taught how to sew,

Rest farm for wives of employees.

and older girls taught cooking and the care of the home and mothers how to cut out children's garments. Domestic

educators have taught how to clean house and the essentials of good housekeeping.

What the race will achieve in the future depends much on the conservation of the health of the children of the nation and in the education of these children. Many efforts have been put forth in the industry for the prevention of disease among children. The establishment of playgrounds is a step in this direction. These playgrounds promote health, education, morality and happiness. They promote health by the effect of sunlight, of fresh air, of exercise on body processes and by inducing appetite and healthful sleep. Play is essential to the education of the child. Playgrounds promote morality and happiness. At many of the playgrounds certain accessories have been provided which aid both in education and in health; among these are drinking fountains, wash rooms, and water closets. Teachers have been provided to instruct in play and in the use of these accessories. Besides recreation for the younger people, club houses have

been erected for the older ones. Much has been done in these club houses to provide recreation for all ages.

All energy is derived from food. Good food is then of great importance. Some plants have provided dining rooms and restaurants, with freshly and properly prepared and well selected foods,

furnished at the lowest practicable price, served under cheerful and pleasant surroundings.

To prevent ptomaine and toxic poisoning, commissaries are oft times essential in order that food may be properly protected from flies and kept from spoiling by means of refrigerators. As with milk, they also fix the standard of quality.

Many a man has been kept awake by a crying child, and injuries have happened from the worry over the sick child at home. Such conditions have been done away with in certain places by furnishing certified milk at a reasonable cost, some companies having herds of cows for this purpose.

Education of the children has not been neglected, and in many places school houses have been erected for the children of employees, the teachers furnished by the State. Churches have been built.

Good housing is essential to both health and contentment. Here the workman builds up his strength to perform life's duties. Much has been done in the erection of excellent houses on healthful and sanitary sites, rented or sold at reasonable rates. Many have all modern conveniences.

Construction camps have been improved. The one that is shown upon the screen has the appearance of a tuberculosis sanitarium and is just as good in construction.

Of distinct economic value has been the encouragement given by employers to those living in mining and industrial villages by fencing in plots for gardens, assisting when

necessary in plowing and fertilization, and stimulating the employees and encouraging them in thrift and industry by offering them prizes for the best gardens. These gardens reduce the cost of living. The amount of vegetables grown is often more than enough for the family. Some have a surplus to sell.

Gardens promote health by bringing the members of the family into the fresh air and sunshine. They mean cleaner yards and better care of drainage and waste, thus preventing odors and the breeding of flies and mosquitoes. Gardens provide a greater variety of food. This is important, because many eat too much meat, and an excess of flesh diet is not conducive to the best work, growth, or health. They tend to abolition or the confining of domestic animals. Gardens promote morality, keep the owner from the saloon and promote his own self-respect. Gardens help make homes and have a refining influence on the family.

By way of illustration I have placed before you some of the general lines of welfare work which are now being carried on by the iron and steel industry. Every one of these topics in the outline at the head of this paper has had careful consideration, and, as you have seen by the pictures, has been carried to an actuality, some companies excelling in one direction and some in others. Every line of welfare work has been well done in some place, and this excellence is spreading. Millions of

dollars are being spent annually to improve the conditions of labor in the iron and steel industry.

It is a great thing to relieve suffering, but it is far greater to search out and remove the causes of disease, of penury and of crime, and to feel that we can say with Abou Ben Adhem: "Write me as one who loves his fellow-men."

When I see the large number here present, all interested in this welfare work, all interested in helping their fellow-creatures, I feel like exclaiming with Shakespeare:

> O wonder,
> How many goodly creatures are there here!
> How beauteous mankind is! Oh, brave new world,
> That has such people in't.

Surely no work becomes you better, and we all hope that the outcome will help to realize the vision of Tennyson:

> Ring out the old, ring in the new. * * *
> Ring in the valiant man and free,
> The larger heart and kindlier hand;
> Ring out the darkness of the land,
> Ring in the Christ that is to be.

(Applause.)

THE PRESIDENT: This is a brief though comprehensive and eloquent statement of what you are doing for humanity. What a refutation of the sometimes expressed idea that you are living only to accumulate dollars. The subject will now be discussed by Dr. Sidney McCurdy, Chief Surgeon of the Youngstown Sheet and Tube Company. Dr. McCurdy.

PRESENT SCOPE OF WELFARE WORK IN THE IRON AND STEEL INDUSTRY

SIDNEY MCCURDY, M.D.

Chief Surgeon, Youngstown Sheet and Tube Company, Youngstown, Ohio.

I take it that in Society and in the products of Society, the fundamentals at stake are profit and waste. Those of you who hold positions of trust for humanity are interested in increasing the production of the world's goods to the greatest degree in order that all may be raised to a higher level and enjoy a more comfortable existence, and that the world may be better off for your having lived and employed your great talents for the good of mankind. You are interested in waste and the prevention of waste, inasmuch as waste diminishes production and postpones the ultimate goal toward which we are all striving. In the past increased productivity has depended upon invention and the capital to finance it, and so it must in the future; but it also depends for its success upon our ability to adapt the invention to human beings and the human beings to the invention. Our workers must be healthy and able to do their part, for sickness is a menace to any industry and in the last analysis a partial or complete loss.

WEALTH AND HEALTH.

The wealth of the world is in direct ratio to the health of its inhabitants. If we accept the statistics of Professor Fisher of Yale University as accurate, when he says that the productivity of a normal human being is worth $2,900, then in the plant with which I am associated, in which there are 8,000 men, it is easy to see that during a large part of the time we control $23,200,000 worth of human machines, and that if our human machines are going to work as well for us as do our mechanical devices we must care for them as scientifically as we do any other part of the organization.

In his most able and instructive address, Dr. Darlington has pointed out to you the means to be used in combating the great economic loss due to human waste. I agree with him entirely and hope that we will all throw in our power and influence toward the side of human efficiency and health. Through being in this work, I see very clearly that one of the steps that will make this movement a success is the co-operation of the men, and how we shall obtain that is a matter interesting to all.

Education by Example.

The only method that can be used successfully to gain the co-operation of the employe must, I believe, be by the way of slow and careful education with gentle force. A large part of our men have been accustomed to unsanitary living since birth and are unable to appreciate the value of a change. The best place to begin is during the working hours, and it is here that our most good will be done. Example is the wonderful teacher of us all, and I see no superior way to begin the education of the industrial worker than to furnish him, within the gate, a sample of sanitary conditions which will impress him so much that never again will he tolerate outside conditions as they were before. Think of the mental effect of the sanitary toilet, the locker room and the wash rooms, where the worker can change his clothes, clean up and return to his home as does anyone else. Think of the educative value to the mind of the clear, clean, wholesome water bubbling from the sanitary drinking fountain, and of the grass plots, flower beds, and clean yard as compared to the unsanitary out-house, the ill-kept house and the yard devoid of grass and littered with rubbish and beer bottles. Compare the mental effect of the Emergency Hospital, with its clean floors and spotless nurses waiting for the injured and suffering employe, with the old methods of handling accidents, and one sees that the example set by the company in the scientific application of industrial sanitation is one that will reach the home and give us a home more adapted to the American Standard of living and health.

Normal Growth is Gradual.

Men who have not been accustomed to sanitary living cannot be expected to embrace a new method of living at once. Habit once formed is a hard thing to break up, and in any education along the lines of better living we must not be discouraged if the worker does not seem as enthusiastic as we expect. If the sanitary appliances are in the plant, and the worker is there taught to use them by foremen, who can be reached by lectures, and the individual by the distribution of circulars written in the various languages, it can only be a question of time before the worker will be as much interested in sanitation as ourselves. Suppose a foreigner does at first place coal in the bath-tub, I feel sure that he will not do it long, and I am equally as sure that his children, our next generation of workers, will know better. Let us be patient with those who do not understand cleanliness, and let us educate them by means of pamphlets in their languages and with talks given at their social gatherings.

Reaching the Homes.

We have not been in as close communication with the home as is necessary for the social betterment and friendliness. The worker is still suspicious of our endeavors in his behalf, and I know of no way more efficient to allay such suspicions than to be absolutely honest with him and to send the social worker into the home to actually teach the wife and mother how to keep the house, and care for the baby, and in general to disseminate knowledge of right living and the prevention of disease. The visiting nurse during times of sickness can furnish instruction in the care of the sick and show the invalid that the industry is interested in its workers during their adversity as well as their prosperity. Honestly done, this cannot but help to promote a more friendly feeling between the home and the industry, and change the sentiment too often felt toward industry, that of an unfair enemy. I believe that any industrial plant that has tried the experiment of furnishing a Social Welfare House outside the plant

where reading rooms, baths, amusements, lectures, and instruction in the American standards of living are given, has never regretted the action taken.

We must give our influence and weight of power to further the action of boards of health. It is the one agency that can insist upon sanitary homes, and we must see that it has the financial equipment to do its work and the power of public opinion as its force.

Conclusion.

Finally, gentlemen, let us not forget that an industry made up of men who are willing to take the broader view of life and work for the social good is a better industry from the very fact that it has attached to its organization the spirit of brotherly love. In conclusion I wish to thank you for the honor conferred upon me in inviting me to discuss this excellent paper of Dr. Darlington, and I wish to leave three thoughts with you: First, sanitation is a purchasable commodity. Second, it requires patient education for its fulfilment. Third, education can best be carried on by means of kindness, example, and gentle force. I am sure that sanitation will displace filth as does nobility the ignoble, if we but follow the advice so well expressed by James Russell Lowell, when he said:

> "Be noble, and the nobleness that lies
> In other men, sleeping but never dead,
> Will rise in majesty to meet thine own."

(Applause).

The President: The committee in charge of the program decided to ask the President at this banquet this evening to call upon various members of the Institute who have not heretofore participated in the exercises of the evening.

As glad as all of us are to hear from what we might call the old stagers, who are always eloquent and entertaining and instructive, it has been decided to give some other gentlemen, some of whom are young and all of whom have had little if any chance for preparation, an opportunity to at least let you see them. So I am going to call upon these gentlemen one by one.

But before taking up the list I am, by request, going to give Mr. James A. Farrell an opportunity to convey to you a message which has been delivered to him by the Iron and Steel Institute of Great Britain. Mr. Farrell. (Applause.)

Mr. Farrell: Mr. President, Ladies and Gentlemen, the character and scope of the papers presented at this meeting are of much interest to the iron and steel industry, and aside from their educational and productive value they are of a representative character, technically and commercially, and reflect credit upon those who have given time and talent to their preparation.

A professor of psychology in one of our leading universities recently said: "To prevent waste of energy, all possible distractions should be removed, thus leaving the mind free to concentrate on the work in hand." If this gentleman had been present at our meeting to-day, and had listened to the splendid papers presented by the members of this Institute, and by others identified with the scientific development of the industry, he would probably have reached the conclusion that those associated with the iron and steel industry conserve their energy, increase their efficiency and thrive on distraction, since no important achievement in the progress of the steel industry, scientific or commercial, has been achieved in an atmosphere of philosophy.

The committee on arrangements, on behalf of the officers and members of this Institute, desire to express their appreciation of the co-operation shown by those who have prepared and discussed the papers at this meeting, since it is only through the interchange of ideas respecting matters of common interest that we can expect to increase the

efficiency of our productive businesses, economically, commercially and industrially. The committee is also greatly indebted to its efficient Secretary, Mr. McCleary, for his efforts to provide an interesting program for our members.

On the 7th of May, two weeks ago last night, I had the honor of attending the proceedings of the Iron and Steel Institute of Great Britain in London. The papers presented were, as usual, of a very high order and many dealt with the consideration of the problems of how best to utilize the by-products of the iron and steel industry. It was thought that many of the waste products might be put to profitable use, since it is a well-known fact that many of the European works now depend upon the resources arising from the employment or sale of their by-products. The annual production of blast and furnace slag throughout the world now reaches the enormous total of two hundred million tons, and studies are being made as to the utilization of the slag, and several papers were read at the meeting dealing with that subject. Needless to say, its members, judging from the wide range of papers presented, are alive to the necessity of further investigation and research.

Subsequently, at the annual dinner of the Iron and Steel Institute, I had the pleasure of offering the greetings of our beloved President, Judge Gary, and of the 1,200 members of this Institute, to our colleagues of the Iron and Steel Institute of Great Britain, the membership of which is international, twenty-six nations having been represented at that meeting. Our felicitations were received with great enthusiasm. As a guest on that occasion, I felt it a compliment to the American industry to be asked to speak and a privilege to talk before that great body of iron and steel makers of the world, and to deliver to that large assemblage the greetings and good will of those connected with the industry in America.

The work of the Iron and Steel Institute of Great Britain is international in its scope, and its cosmopolitan character is an assurance of what can be accomplished by collective effort in the dissemination of scientific knowledge so necessary to the economic advancement and efficiency of the

world's most important industry. Many of you personally know the retiring President of the Iron and Steel Institute, Mr. Arthur Cooper, the Chairman of the North-Eastern Steel Company of Middlesboro. His uniform courtesy to his colleagues in the iron industry is well known and has left an impression which time cannot eradicate. The new President, Mr. Adolphe Greiner, Director-General of the Societe Anonyme John Cockerill, Seraing, Belgium, is one of the veterans, having just rounded out fifty years of service with that great company. By his untiring energy and initiative Mr. Greiner has done much to place Belgium in the forefront in the markets of the world. Both of these gentlemen asked me to personally deliver to our President, Judge Gary, and to the members of this Institute, their most distinguished felicitations. (Applause.)

THE PRESIDENT: Those who wish to express grateful appreciation of the kindness of the Iron and Steel Institute in these expressions of good will, will please stand. (All rose.)

It is my pleasure to introduce Mr. James H. Plummer, President of the Dominion Steel Corporation, Toronto, Canada. Mr. Plummer. (Applause.)

MR. PLUMMER: I take it as a very great kindness on the part of Judge Gary that he should call on me early. When it was intimated to me this afternoon that I might be called upon this evening to make a few remarks, I recalled the various volumes that I had read containing reports of the meetings of the Institute, and I remembered the exceedingly bright speeches therein reported—all made "impromptu," of course—and I scarcely knew what to do, as I am not an offhand speaker. In fact I doubt if, as a rule, Canadians are. It was just a year ago that Mr. Arthur Cooper, of whom Mr. Farrell has spoken, did me the honor of requesting my participation in the proceedings of his annual dinner, and I heard him say to his neighbor, "I have asked Mr. Plummer to respond for the visitors tomorrow night. We will have a good speech—he comes from

over the other side." The only way to relieve my embarrassment was to explain to the meeting that unfortunately I took after my brothers in England and not after my cousins in the United States. (Laughter and applause.)

These volumes that we get are extremely interesting. One of my colleagues declares that I go to the end of them first, to the entertaining after-dinner speeches. Now, I don't do that. I read the solid matter very carefully. In fact, I read everything so very carefully that only within the last two or three weeks I stole some excellent matter from one of the speeches there recorded, and it made an appropriate item in an address I had been asked to deliver on the question of university life and its connection with practical life afterwards. I have already concealed on my person a verbatim report of Judge Gary's speech of this morning, and I have my eye on some very good ideas in it that I am going to pass out at a meeting next week.

I can't think of any nice amusing story to bring in just at this stage—the proper stage to bring it in according to all the authorities, and some of the gentlemen here are great authorities on the subject. (Laughter.) Unfortunately, I am not. I am rather like the other man that you may have heard of, who was given a good dinner by an old lady. He was going away with nothing more than a good-by, when she asked, "Haven't you got anything to say?" He looked at her and said, "What do you expect me to say? I am not Mr. James H. Hoyt." (Laughter.) I can honestly say this has been a very good dinner, but I am not Mr. Hoyt, and cannot express my appreciation as he can. Nevertheless, I am extremely glad to be called on. In fact, one of my anxieties was lest Judge Gary should forget to call on me, because I did wish to have the honor, on my first appearance at this Institute, to speak a word of greeting from Canada.

We in Canada take an immense interest in the work you American iron and steel men are doing. We have a tremendous admiration for all that you have accomplished, and we have a certain amount of envy for your great success. I had

the pleasure last fall of spending three or four weeks visiting the various plants in England and Germany. On that trip one little remark was made to me that I would like to repeat to you. It was made by a German. We were comparing American and German practice, and my German friend said, "Americans don't have to know much about making steel. They have the ore; all they have to do is to drop it into their furnaces and it turns into steel." There is a certain amount of truth in that.

In Mr. Brassert's very interesting and valuable paper to-day I was especially struck by three or four words. He said, "Such conditions facilitate good furnace operation, but they also tend to retard progress." The time will come, gentlemen of the Institute, when you will encounter the difficulties that we have to face in Canada. You may think that we have fallen behind, but let me tell you that we have exactly the same problems to solve as they have in Germany and as they have in the greater part of England. We have different ore and different coal from yours. Your time will come some day when your great reserve of superfine ore will fail you and you will encounter the same difficulties that we face. If Mr. Brassert and another gentleman who spoke to-day are rightly informed, as no doubt they are, the steady tendency is to lower grades of raw material. We have been so used to overcoming the difficulties of handling this lower grade of ore that perhaps you will be looking to us for a little advice as to how to do the work. At present we are only following you in a modest way.

Among us, in Canada, we hold Judge Gary and his work in connection with the iron and steel manufacturers in the highest possible esteem, and we try in our way to follow in his general lines. Further, gentlemen, I would like to say that in Canada we have the warmest and most friendly feeling for our brothers on this side. It is more than that. We look on concerted action between the Americans and the British—whether they are Canadians or English or Scotch or Irish—as one of the moral forces for uplifting the world, for peace, for harmony, and for everything that is right and good. (Applause.)

The President: We are very proud of our Canadian cousins. I will now introduce Mr. William U. Follansbee, of Follansbee Brothers, Pittsburgh. Mr. Follansbee.

Mr. Follansbee: Mr. Chairman and Gentlemen, as our Toastmaster pronounced my name, somebody over here said, "Poor devil." I rather infer that my sympathizer knows that I am in the tin plate business. I also infer that possibly he has been reading some recent Government statistics, which show that during the first six months' operation of our present tariff law the tin plate imports have increased about 1400 per cent. The last thing Wednesday night before leaving Pittsburgh, I read in one of our trade papers that the sheet line was the weakest in the steel industry; and, unfortunately, I am also a manufacturer of sheets.

This morning when those very interesting papers were being read with respect to manufacturing costs and sales department, I recalled a conference that we were having in our office recently when we figured out that taking the business on which we were losing money and the other lines on which we thought possibly we were making money, and averaging them all up, this net result was a profit of about two dollars per car. A day or two after that our friends of the Pennsylvania lines, west, placed in our hands the new rate sheet, and at the head of the list of those who were to be charged for spotting appears our name. (Laughter.) Mr. Chairman and gentlemen, naturally I am rather of an optimistic disposition, but that was too much, and I started to pack my grip with Detroit as my destination, thinking that I could possibly get a job as a sweeper at five dollars per day when the papers published the fact that Ford had laid off six thousand men. (Laughter.)

No one can afford or even think of being in the steel business unless he is of a determined disposition, and so I determined to find some industry that was running full, and I did —the plant is working overtime. I refer to the conversation factory down at Washington. (Applause and laughter.) Gentlemen, it is a principle of political economy, I believe, that when one industry is doing well activity spreads to other

and kindred industries; and so in my investigations I have found out that this conversation factory requires so much detail and so much care to put down what is going on that the output of typewriters has been very greatly increased. So I was not surprised to see in a publication within a day or two that a typewriter manufacturer has not only declared a dividend on his preferred stock but, think of it, a dividend also on his common stock. (Applause.)

What typewriter company was that? It bears a name with which most of us are familiar, a name that means much to us all. It is not Oscar. He does not live in New York. It is Underwood. On every one of these typewriters that had been declaring a dividend the name of Underwood appears—that magic name. Now, gentlemen, in view of what has occurred in the past, in view of some of the statements that have been made in cases which we will not mention, I am willing to leave to any fair-minded steel man, if combining a factory that is running full, as we have it in Washington, with the benefit that has spread to kindred industries, and topping that with the name Underwood—if that isn't the greatest conspiracy we know in restraint of trade. (Laughter.) Why should not we, gentlemen, here to-night petition the Department of Justice to take action against this largest, this newest and most effective agent that is violating the Sherman Law? I thank you. (Applause.)

The President: That was quite a suggestion, wasn't it? I have the pleasure of calling on Mr. Charles P. Perin of New York.

Mr. Perin: After what Mr. Follansbee said, I feel almost like a criminal to add to the gloom occasioned by the conversation factory.

For ten years I have been connected with a family of Parsees in Bombay who have undertaken to reestablish and develop the iron industry, which 200 years ago in India was a very active one, but which had practically disappeared. I was engaged to investigate their iron ores and to advise them as to the establishment of blast furnaces and steel works. In that work I had the honor of having Mr. C. M. Wells

as assistant, and Mr. Robert G. Wells, who is here to-night, had charge of the construction of the plant for its first operation.

After listening to Dr. Darlington, I see how much we still have to do in India to even approach your condition of welfare work; but we have done a great deal. You may judge how much remains to be done from the fact that only recently I was at a coal field 150 miles from Calcutta, which field is about 25 miles long to 15 miles wide, where they now take out 15 million tons a year from coal seams four feet to thirty-four feet thick. There every few years they have an epidemic of cholera which takes off from 300 to 1,000 people. Two of the English companies have recently employed physicians to look into the sanitary conditions of their men. One of them, Dr. Simpson, told me a few weeks ago: "We had had a terrible epidemic and I could find no way to stop it. I followed up my water system and made examinations of the water. The cholera germ is like a little black comma. I found the water was full of these germs, but I could not find the source of supply. Examining our suction pipe in the Damuda river, I found a cholera corpse drawn over our suction strainer. For days we had been pumping cholera through our entire village."

In our work in India, we have been actuated by a desire to build a modern plant, one which would enable us to compete, as far as possible, with European and more particularly English steel rails, which are shipped into India. After what Mr. Follansbee said I can not help thinking that our economic position may interest you. We have iron ores ranging from 60 to 65 per cent. in iron content that can be delivered for three-quarters of a cent a unit. The coals, which we have to buy in the open market, are delivered at the works for a dollar or less. The freight rate on raw materials is three mills per ton per mile. We can put pig iron f. o. b. ship in Calcutta for fifty to fifty-five cents. The labor conditions are interesting and are constantly improving. We employ at the steel works about 7,000 native men and women, and 159 Europeans. The relative cost of these two may interest you. The payroll for the

159 Europeans is only between five and ten per cent. less than the entire payroll of the 7,000 natives. The pig iron from the furnaces is carried by women. They receive for this service approximately the sum of three and a half annas per day. Their pay has recently been increased. They used to get three annas, or six cents; they now get three and a half annas, or seven cents. Common laborers receive four annas per day—eight cents. Their pay is 50 per cent. better than before our entry into the country, and they are entirely satisfied.

We feel now that we can come into this market, since the American Government has kindly removed the tariff and given us an opportunity to place our surplus product. In a few weeks we expect to appear in San Francisco with a cargo of rails. It is needless to say that we can break the American rail pool, if there is such a thing. I am sorry to have to tell you this, but I must state the facts.

I was brought up in a free trade school, and I used to think protection a mistake. I am interested in a blast furnace in this country which is now shut down and has been for some little time. The free trade idea is very beautiful until your interest is attacked. But our friends across the border in Canada have put $6.10 on rails, and they are trying to keep out the foreign product. However, we in the United States have taken down the barriers, apparently anxious to help people who get six cents a day to sell their product to this country. I am sorry that I am the instrument through which it is being done, but I am afraid that your condition is going to be very much like that of Uncle Eb. Uncle Eb used to attend the revival in Nashville, but this year he wasn't very keen about telling his experience. Presently the Parson spied him, and said, "Come on, Uncle Eb, tell us what the Lord has done for you." Uncle Eb very reluctantly arose and said very shortly, "The Lord hain't done nothing for me. I am damn near busted." (Applause.)

The President: The gentleman who will next speak is probably personally known to you all. It is my pleasure to call upon Mr. Frank Baackes.

Mr. Baackes: Mr. Chairman and Gentlemen, the longer I am connected with the steel business, the more I am impressed with the progress that is made in the manufacturing end of the work. It is wonderful.. But I am also impressed with the little progress that has been made in the commercial end, which I have the honor to represent. It seems every time that we have a depression, caused either by overextension, by political causes or otherwise, the commercial end loses its head. Now, gentlemen, it is true that we cannot control these depressions. They are bound to come. We cannot control the politicians of this country. They are going to do whatever they please. We cannot revise the tariff as we may like to have it. But generally there is no reason why, in the face of all that, what we do sell we should sell without a profit. Nobody compels us to do that except our own cupidity, or our own lack of judgment, or our own lack of knowledge of conditions. If we studied conditions, if every man in this room knew that the country could not take the product of all our mills, and he was satisfied to sell his share and sell it at a profit, then we could snap our fingers, gentlemen, at the politicians in Washington. So long as we can make a little profit, let them do whatever they please. By and by they will come to their senses, and we can bide our time as long as we have enough in our pocket to pay our bills with. Those men in Washington do not know anything about business. If they did, they would not go to Washington (laughter and applause), they would be in business and make money (laughter). But to earn their salaries, they must be up and doing something. Now, therefore, let us be up and doing something. Let us take care of ourselves, and do not let us blame our own shortcomings on somebody else, as we are doing all the time. (Applause.)

You know this selling game is a great game. I have been in it for thirty-five years, and at both ends of the line. One of the strangest things about selling goods is that we believe the man we are going to sell to rather than each other. The man we are selling to, probably, is going to do us if he can. I have noticed that the average buyer, un-

consciously perhaps, has a desire to make even his best friend work for him for nothing. (Laughter.)

And that is only natural, because if I buy goods close to cost, just that much is my position superior to my competitor's. Now, realizing the buyer's temptation, gentlemen, why do we trust him instead of ourselves? That is what I cannot understand. I can talk to a competitor. He don't believe me and I don't believe him. But let a buyer talk to me, telling what he can buy for, and I believe him in a minute. And what do I do? His price, or my competitor's price, I make my price. That is a fine way of doing business, isn't it? There is hardly a salesman that has courage enough to stand by his own price. All he knows is to sell at the other man's price. Now, what is the use of having a salesman if that is the case? This great iron and steel industry is spending millions and millions of dollars for our work, and in times like this I assure you we give them mighty little in return.

But conditions are not so bad. They might be worse. We are still having something to do, every one of us, and we will continue to have something to do. This great United States can stand almost anything. It will continue business and work will go on. With the great crops, and with the commercial world liquidated to a standstill, you will see business coming in by and by; and I hope that the commercial end of this business will do its part by having judgment enough not to load up the industry at present prices for years to come, and then expect the manufacturing end to work for nothing.

Gentlemen, let us not hypothecate the future. Let us not drive the manufacturing end of this business to despair by continually demanding lower costs. Every time we cannot meet the price we go to the manufacturing end, and we say we must have lower costs. That must result in one thing or the other—either the manufacturing end can't make money or the concern must turn out goods that we ought to be ashamed of. Let us make up our minds to get a fair price for our goods, and there is no law in the world that will prevent you from getting it. Let us show the manufacturing end that we can do just as much for the industry as they can.

We are the people that make the money. The manufacturing man can't make a dollar. All he knows is to make goods. We are the people that have to make the money. Now, let us do it, and let us get a living price that will enable us to take care of our employees, to take care of our stockholders and retain our own self-respect. (Laughter and applause.)

THE PRESIDENT: The next gentleman who will be called upon has our respect, our confidence and our affection, and we would go home very much disappointed if we did not call upon him for a few remarks. I have the honor to introduce Mr. James H. Hoyt. (Applause.)

MR. HOYT: Mr. Chairman and Gentlemen, I am gratified at being selected to-night, because I am selected—I have it on the authority of our Chairman—by reason of the fact that I am not yet an "old stager."

I was very much interested in the remarks of Judge Gary this morning, as I always am in all of his remarks. I was particularly impressed by the way in which he impressed upon you the necessity of helping each other. That is generally good not only in a moral sense, but it often turns out to be good in a pecuniary sense. I can illustrate the truth of what Judge Gary said by telling you a little story. A Hebrew gentleman went abroad lately to do some business in London and incidentally to meet his wife and bring her home. When he arrived there she asked him how he enjoyed the voyage. He replied: "I had the most splendid time on the ship I ever had in my life. The first night I was asked to play poker with the finest gentlemen you ever saw. There was a British Lord there, and a Russian Grand Duke, and a German Baron. The stakes were pretty high, but I thought I would stay in the game. When I picked my hand up I had three aces. I drew two cards and picked up two queens, so I had a full house. Two of the others drew three cards each, and the Russian Grand Duke drew two. I broke the pot for the limit, and everybody dropped out but the Russian Grand Duke. He raised me, and I raised him and then he raised me, and I raised him, and finally he said,

'Well, I don't want to rob you. I will call you. What have you got?' I said, with pride, 'I have a full house,' and laid my cards, faces up, on the table. He took his cards, threw them on the table with the discards, faces down, and took in the pot, saying, 'I have four fours.' I asked, 'Well, don't I get a look in? Can't I see them?' He answered, 'I want you to understand, sir, that you are playing cards with gentlemen, and our word is good.' I said, 'All right.' And do you know the rest of the evening I didn't lose a single pot." (Laughter.)

It is very necessary for you gentlemen to exercise prudence in the management of your business, and that reminds me of another story. Two Hebrew gentlemen were going abroad on the Olympic about two months ago. One was Mr. Moses and the other was Mr. Jacobs. They occupied the same stateroom. Moses thought about nine o'clock that he had better retire, but Jacobs preferred to sit up and smoke a cigar. Going down an hour later, Jacobs turned on the electric light and was astonished to see his friend's hair done up in curl papers. Moses had evidently just shaved himself, he had rouged his cheeks and blackened his eyebrows, and he had on a lady's night cap with considerable lace on it, a lady's nightgown and a string of blue beads around his neck. As Jacobs turned on the light and saw Moses, he said, "For the love of heaven, are you crazy!" "Oh, no," said Moses, "this is not craziness, this is not madness, it is prudence. Don't you remember when the Titanic went down that the women were put in the boats first." (Laughter.)

This is the time it seems to me for optimism. I mean real optimism—optimism like that of Charley Schwab. I don't mean the sort of optimism of men in high places in this country, both in executive places and in the legislative halls, who believe in an optimism that does not care what happens as long as it does not happen to them. I believe in real and earnest optimism like that of the gentleman who was suffering from St. Vitus dance, but was extremely grateful that at the same time he hadn't the rheumatism.

It has been a costly experiment for the people of this

country to find out how very inefficient a man may be when he is required to do something instead of merely to say something. But it has been worth the cost so far as the future of the country is concerned. We should also be optimistic, gentlemen, because after all the people of the United States are sensible people, and by and by, some day or another when they learn the lesson which they have got to learn, things will be better, as Judge Gary said this morning.

I noticed in the New York *Sun* that the seven months' operation of the new Tariff Law had resulted in changing a considerable balance of trade in our favor to about $114,000,000 against us. The report also showed that in the month of April, as compared with the same month last year, our imports had increased by over ten millions and our exports had fallen off nearly forty-four millions in a month; so there was in a single month a shift of $54,000,000 against the Government of the United States. But, gentlemen, it has been the history of our country that when they get fooling with the tariff and the people of the United States find that we are suffering as a result, they invariably get busy. Judge Gary said we are six months nearer the change than we were when he last spoke to us.

Of course, the Mexican situation is not particularly pleasant. I was told of a young Irishman, who broke into a saloon where a fight was going on and asked, "Is this a private fight or can any one take part in it?" (Laughter.) We did not even ask whether it was private fight before we got into it. But we are there and we hope for the best, and probably when Huerta is eliminated, as there is a chance that he may be, we can congratulate ourselves on having substituted in his place that stainless gentleman, that noble minded patriot, Villa, and that everything will be greatly improved as a result.

But the hour is late and I have little more to say. I have been very, very much impressed by the tremendous energy in the manufacturing end of the business in the way of improving production, but especially what you are doing in the way of welfare work. Gentlemen, there can be no doubt about it that efforts like yours will in time meet their proper reward.

The pendulum is swinging. As I looked at those pictures which were thrown on the screen and listened to Dr. Darlington's admirable and eloquent speech, I was reminded of that beautiful poem of Lowell's, The Vision of Sir Launfal. You will remember how Sir Launfal started out to seek the Holy Grail, and as he rode out of his castle there crouched at the door of the castle a leper. Sir Launfal threw him a piece of gold and shuddered at the mere sight of him. But after years spent in the search of the Holy Grail, not having found it he returned broken in health and fortune, with a crust of bread and with a tin cup fastened at his belt. As he came near the castle he again found sitting beside the door the leper. And he who had been so disgusted and who had shuddered at the sight of the leper when he started on his useless quest, now went to a nearby spring and filled the tin cup and offered it to the leper. He then took the crust of bread, broke it in two and gave the leper half. Then the leper stood before Sir Launfal glorified, shining and straight and tall, and when the leper spoke, as the poem says,

> His words were shed softer than leaves from the pine,
> And they fell on Sir Launfal as snows on the brine,
> That mingle their softness and quiet in one
> With the shaggy unrest they float down upon;
> And the voice that was calmer than silence said,
> "Lo, it is I, be not afraid!
> In many climes, without avail,
> Thou hast spent thy life for the Holy Grail;
> Behold it is here—this cup which thou
> Didst fill at the streamlet for me but now—"

and then he added,

> "It is not what we give, but what we share,
> For the gift without the giver is bare."

Now, gentlemen, in the welfare work you are following the spirit of that beautiful poem. You are taking the trouble of giving yourself to the work, and the reward must come. How

can any American be anything but optimistic after listening to the papers by Dr. Darlington, and see what you are doing to help and uplift men at the mines and the mills?

One word more and I am through. It is another quotation from a little poem written by a gentleman I wish we had with us now, John Hay. This little poem, which everybody should commit to memory, says—

> Behind the dark of every cloud,
> The sun is always shining;
> So let us turn our clouds about,
> And always wear them inside out
> To show the silver lining.

(Applause.)

The President: I am pleased to say that the committee in charge of the program for the evening had intended to include only those who might be termed new speakers because they had not been called upon before, but when the Secretary sent letters of inquiry to members of the Institute concerning the names of those who could be called upon with the expectation that their remarks would be well received, the call was so large and so numerous in favor of Mr. Hoyt that the committee was forced to put his name on the list.

It is my pleasure to introduce Mr. Hugh Kennedy, Vice-President, Rogers-Brown Iron Company, Buffalo.

Mr. Kennedy: Mr. Chairman and Gentlemen: As I came into the meeting this morning an old friend from Pittsburgh grasped my hand and said "How are you, Kennedy? Why did you leave Pittsburgh, the center of the iron and steel industry, and go up into the frontier at Buffalo?" He was the third man that asked me practically the same question to-day. You know a great many people are going about asking questions. Such a man spent all his time thinking up and firing at his club friends hard questions which they could not answer. Finally they got together and made a rule that any man who asked a question that he could not answer himself would be fined ten dollars

Nothing was heard from the questioner for some time, and then one day he said, "Gentlemen, can you tell me why it is that a ground hog in digging a hole in the ground leaves no dirt around the doorway but cleans everything away perfectly?" "You answer it yourself," his friends replied. "Well," he said, "he digs it from the bottom." Thereupon one of his friends said, "How does he get to the bottom?" To this the man said, "That's your question. You answer it." (Laughter.)

With your permission I wish to tell of a dream I had. I dreamed I stood on the brink of Niagara Falls. I can't tell you who was with me but it was some one like our genial secretary with a bright eye, a pleasant smile and a firm grip. I noticed that the falls were dry, and I asked, "What is the matter, what has happened, there is no water going over the falls?" "Why," he said, "don't you know? That is not strange." And I answered, "No, I don't know. Why is the water not going over?" "Don't you know," said my companion, "that the Canadian government and the American government some years ago got together and figured there was an amount of water going over the falls representing 6,000,000 estimated annual horse-power which at 10 tons of coal to an annual horse-power would equal 60,000,000 tons of coal going over the falls every year; or 200,000 tons of coal per day, 300 working days per year, which at 1913 values would represent a half-million dollars per day. That went on from year to year. The American people and the Canadian people sat by and never realized that here was a wanton waste of power. Why," he said, "from where you stand to Lewiston is seven miles of level plateau and from the Rapids above there is a 200 foot fall to the gorge below. Waking up to the possibilities, they harnessed that 6,000,000 horse-power, that 60,000,000 tons of coal, by constructing two enormous canals on the plateau, one on the Canadian and one on the American side, connected with power plants on both sides at the bottom of the gorge; the flow of water into these canals being controlled by great gates at the head of the rapids, a low concrete dam being placed at this point

to divert the water into the canals when the gates are open. Industries all over this broad Niagara frontier country are now driven by that mighty power." "What about public sentiment?" I asked. "At first," he said, "they could only use the power at night because the people who came here, the brides and grooms and visitors who came from all over the world wanted to see the falls. But at night, after every one had retired and everything was quiet, the gates were lifted and this mighty power was used for industrial purposes. Now on Saturday night after the week's work is done, the gates are closed and the water is allowed to flow over the low dam and the falls, and the people who come here on Sunday can view the waterfall in all its beauty. But there are now more people coming to view this wonderful development of electrical power than come to see the great natural wonder."

"And that is not all. Way back in 1913 the production of coal in the United States was about 560,000,000 tons. It has doubled in eleven years. Men were going way down in the mines, lying on their sides, digging coal in veins not over two feet in thickness. Why, in 1913, we used 20,000,000 tons of coal in Pittsburgh, New York State used 15,000,000 tons, Greater New York 9,000,000; Canada, through Buffalo ports, about 4,000,000—in all, about 48,000,000 tons of coal—and here is this power representing over 60,000,000 tons of coal, delivered without charge for freight or handling."

"And there are other things. You know that back in that time we had discussions. We were talking of working this kind of ore and that kind of ore, but didn't appreciate that the high grade ore in this country was not inexhaustible, and year by year was diminishing, so that instead of using two tons of ore, as we did then, we are now using three tons of ore to make a ton of iron; and that instead of about 6 per cent. silica then, we are now using ore running 20 to 30 per cent. in silica. Then we came to appreciate the most marvelous and magnificent part of the development of the great iron and steel industry in this country; the shipment of material over the Great Lakes, in 10,000 ton

boats, loaded and unloaded by electrical machinery, enabling the boats to return light to Duluth and bring ore to lower lake ports at forty-five cents per ton, and make money; the steel barges on the canal, towed by electric motors, with hatches opening the whole length of the deck, making it possible to load and unload their cargoes with electrical machinery and to make a profit in carrying pig iron to Eastern markets at fifty cents per ton; and the ship canal terminal extending from Tonawanda to Lockport, the Tonawanda Creek being lined for miles with concrete elevators for the storage of grain and connected by a series of electrically driven conveyer belts delivering this grain to elevators on the Hudson River, thus making it possible to deliver grain in winter as well as in summer. Tonawanda, which was once the greatest distributing point of lumber and building materials, is now the greatest center for the manufacture of Portland cement made from blast furnace slag; also for the manufacture of slag bricks, both materials being delivered to the Eastern market via the canal."

"And don't you know that from the point where you stand you are within a night's ride of 75 per cent. of all the population of the United States and Canada." And I said, "What about the Pittsburgh district?" "Why," he said, "this is the center of the Pittsburgh district. This is the center of the world." Mr. Chairman it was only a dream. (Applause.)

The President: I call upon Mr. George M. Verity, President of the American Rolling Mill Company, Middletown, Ohio.

Mr. Verity: Mr. Chairman and Gentlemen: Mr. Follansbee and Mr. Baackes have just proven to our satisfaction that it takes a great deal of courage to be an optimist at a time when sheet iron is carrying a profit of $2.00 per ton and when the Interstate Commerce Commission is insisting that we turn that $2.00 over to the long-suffering railroads in lieu of a five per cent. advance, and when our Sales Departments

admit that they are giving away another $2.00 per ton just to prove that we are good fellows.

I wish, however, to proclaim myself an optimist and to try to give you an optimistic thought. It is fortunate indeed that business, subject as it is to frequent and prolonged periods of depression, is a running stream and not a placid lake or stagnant pool. There is a limit to the height of a dam that can be built across a running stream. We have been doing a great deal of damming of one kind or another in the period just behind us. Big business has come in for its share of damming, and successful business of every kind seems to have been discredited. There are those who have had the temerity to damn political parties. There has been damning and counter-damning in a frantic attempt to ascertain what is the matter with business. All this has resulted in building a dam of depression across the stream of business, which I believe, with a great many others, has already been built as high as it can go, and that it is likely to break through at any moment and let out a flood of new business that will again bring happiness and prosperity to all of our people. (Applause.)

Now, Mr. Chairman, I have just one other thought that I would like to leave with you this evening. It seems to me that this Institute, representing the great iron and steel industry of the country, the barometer of business as it is, could do a great service to its members, to industry generally and to the country at large, by using its great influence in attempting to bring about a more uniform, a more stable and a more advanced labor condition throughout the country, just as our Welfare Department has so successfully promoted "welfare work" through the able direction of Dr. Darlington, and just as "safety first" has been promulgated throughout the entire country through the efforts of the American Museum of Safety. We have done much to improve practice in every phase of the iron and steel business. Any manufacturer who has not availed himself of the knowledge of the day in that respect has only himself to blame. But, while we have made great progress in practice and in production, labor conditions are still a matter of competition between

individual companies, and each organization is left to create such labor conditions as it can, or as it thinks best in the conduct of its business.

It seems to me that we will sooner or later have to consider carefully and meet wisely the general industrial unrest of the country, and if this great Institute could bring about a better understanding between employer and employee, and create that feeling of mutual interest that must exist if their common prosperity is to be enjoyed, to the end that we might both get rid of the dishonest labor agitator and bring honest labor to our aid, we would then bring about a condition of affairs that would add very greatly to the progress and stability of our country.

It is a matter that cannot be accomplished in a day, but it will have to be started sooner or later, and it seems to me that there is no time like the present. (Applause.)

The President: I will call upon Mr. Severn P. Ker, President of the Sharon Steel Hoop Company, Sharon, Pa.

Mr. Ker: Mr. President and Gentlemen of the Institute: As you are all aware your committee for this evening, through our genial Secretary, has been engaged in some research work to see if they could not find down here in the ranks some germs of oratory or pearls of wit for your entertainment. Some vandal has evidently proposed my name. I hope he is here. I would have him suffer with you. When I learned that I was to be called upon for some impromptu remarks I felt great pity for myself, but since getting on my feet that has given way to an overwhelming pity for you; and I feel that that sentiment will be unanimous before I get through.

I have been very much entertained and instructed at all the meetings of the Institute. I believe I have never missed one. I feel that the time taken is more than repaid. We have learned much from those who have heretofore spoken to us, so much that we could afford to give up very many times the amount of time that it takes us to come to these meetings.

This Institute has done a great thing in promoting good fellowship and in instructing all of us, in some way or another, to become better producers and more expert in the art of steel making.

We have certainly fallen on very sad times. We have been told how hard it is to be optimistic, but nevertheless I would bring you a message of good cheer. It seems to me that an industry so essential to the welfare, so indispensable to the life of this nation, cannot go to a much lower point than it is now. I am reminded of a story told of one of the older iron and steel manufacturers of the Pittsburgh district, Mr. Bennett, of Graff, Bennett & Co., who in their day were prominent in the industry. In a period of great depression, such as this, he used to come into the Duquesne Club, which was even more than to-day composed of iron and steel men. The question was, just as it is now, when we meet our fellow manufacturers, "How is business?" One day Mr. Bennett, as he came into the club house, was asked the usual question, and he answered, "Oh, business is looking up." He marched off to his table and sat down to lunch, but his friend looked after him rather wistfully and a little puzzled. Pretty soon it went all around the club that Mr. Bennett had said that business was looking up. His colleagues could not understand it, and they were laying for him as he came the next day. He was again asked by one of them, "Mr. Bennett, how is business?" And he replied as before, "Our business is looking up." He then undertook to pass on, but they closed on him so that he could not escape, and one of them said to him, "Mr. Bennett, how can you say that business is looking up? We would like to have you explain what you mean. How can your business be looking up when ours shows no improvement whatever?" Mr. Bennett answered, "You fellows don't understand. The darn thing is flat on its back and can't look in any other direction." (Laughter.)

I think that about illustrates the condition of business to-day. But that we are going to see better business is, I think, indisputable, because almost any move must be a move for the better. We will probably not see any very

great relief from the excited state of the salesman's mind, as Mr. Baackes described it, until we see our order books somewhat more nearly filled, and that we cannot hope to see as long as Mr. Follansbee's Washington wind-jamming factory has such a large output. But there is some hope in the thought that Congress will soon have to adjourn and go home. We have a Congressional election this Fall, and they are probably interested in that election. It may be that much more legislation cannot be passed before that enforced adjournment, and I rather take it that they will find it somewhat difficult to talk political theories successfully against an empty dinner bucket. (Applause.)

That the salesman is capable of doing a great deal of harm by his inability to make a great deal of money for his company, is true. However, it seems to me that if more attention was paid to the very excellent suggestions made in the papers read by Mr. Bray and Mr. Robinson that we would see improvement in that branch of our business, because the man who says the last word, yes or no, to the taking or leaving of an order is the man, in most companies, who has the right to know and must know what his cost sheet shows and must be responsible to his directors, to his employees and to his stockholders for the results of his operations. Mr. Baackes says that the manufacturer cannot make money and that it is the salesman who must either make it or lose it. That reminds me of another incident that occurred some years ago, at a discussion among bar iron manufacturers as to what ought to be the market value of their product. At the conference there was one gentleman, the head of his company, who did not often speak, but when he did we all understood what he was talking about. We were not getting very satisfactory prices for our products. I think we were losing money on them, certainly many of us were. He became very much exasperated at the failure of those present to express sentiments that met with his approval as to the proposition of securing better prices for those products. Finally he got up and shook his fist at the rest of us, and with a good deal of profanity said, "The trouble with you fellows is that you run your mills to

make bar iron. Our company never ran its mills to do that. We run them to make money." I think if more of us ran our mills to make money and not to make steel, except as a means of making money, probably Mr. Baackes would be more cheerful. (Applause.)

However, we all of us who have been in this business for as long a time as I have, have seen these depressions come and go, and with each turn of the tide we have reached a higher point of prosperity than has ever been attained before. I think that condition will be repeated. The dam which Mr. Verity described has undoubtedly been built very high, but the flood back of it must some day come out. I think it is true of almost every line of business, that customers are operating with bare stocks. Everything has been liquidated, except labor, and our friends at Washington have been very busy trying to solve the interesting problem of increasing the wages of labor and decreasing the cost of living, that I cannot see any hope at the present time. (Applause.)

The President: This finishes the regular program, and it is eleven o'clock. Have you any wishes to express?

(Cries of "Schwab, Schwab.")

The President: I warned Mr. Schwab.

Mr. Schwab: Yes, but the Judge did not keep his word not to call on me. This was one time when I was to be exempt. It is the only time that I have not had a chance to prepare an impromptu speech. (Laughter.) There was such a note of pessimism, with few exceptions, throughout this room this evening that it commenced to make even me, a confirmed optimist, pessimistic. I know that you want something humorous from me to-night, but how in the world is it possible for a man in this atmosphere to get into a humorous mood? I feel very much like the fellow did that participated in a function a short time ago over in London. They were having a great pageant. They called it a Roman pageant. The men who managed it forgot that the climate

of London was not like the climate of Rome. The fellows who took part in it, clothed in a sheet and a pair of sandals, were very uncomfortable during the period when the pageant was in progress. When it was finished the men hurried home to get into comfortable clothes. One of them met an old lady. The old lady asked him, "Are you Appius Claudius?" And the poor fellow replied, "No, ma'am, I am not; I am un'appy as 'ell." (Laughter.)

That's the way I felt when I heard all these speeches. There is another thing that formerly enabled me to make some fun during the evening. I used to have some sport with Uncle Joe Butler, who is doing so much for the McKinley Memorial; but times are hard and I don't dare say anything about that now, for fear he will ask for a contribution, and you know I can't stand that. (Laughter.) Then I read a report of the iron association of which Uncle Joe is president. It showed that they lost a dollar a ton, and I thought of the story of Mr. Carnegie, when a man came to him one time and asked, "Mr. Carnegie, what does it cost to make rails?" Mr. Carnegie answered, "Thirty dollars a ton." And the man asked, "What do you sell them for?" and Mr. Carnegie said, "Twenty-eight dollars a ton." The man looked up and said, "How do you manage to make the money that you do?" "Well, you see," said Mr. Carnegie, "our big output helps us out." (Laughter.)

I am rather pessimistic now, but I believe that the time is coming when things are bound to improve. That is a comfortable way to feel, especially when you are trying to borrow money to bolster yourself up, because only in that way can you get people to give you their money. Business is bad, it's darn bad, but in my opinion it will improve. I haven't got any more to say on that subject, or any other subject, to-night than to tell you the story about Hatfield. Hatfield came home the other night a little late, and his wife said, "Where have you been all evening?" And Hatfield said, "With Mr. and Mrs. Farrell." "Why, no," said his wife, "you haven't. Mr. and Mrs. Farrell have been here all evening." "Well," Hatfield said, "that's my story and I am going to stick to it." (Laughter and applause.)

THE PRESIDENT: Gentlemen, what is your pleasure?

(Cries of "King," "King—") Mr. King is called for.

MR. KING: I have attended all the meetings and dinners of the American Iron and Steel Institute, and I can say that I always expect to take something home with me in addition to what I brought. But I cannot truthfully say that I have heard much to comfort and encourage the men who may have come to this meeting with some such hope. But I cannot help feeling inspired in looking at the faces of the gentlemen of the Institute here tonight with a feeling that American business men will not be discouraged, and they are not disheartened by the handicaps placed upon their business by those who ought to assist it. We have been fighting for decent business for some years with one hand tied behind our back; for while our competitors in other countries have been encouraged by their own governments, we have been trammeled by our own government. It does not seem to me that the American manufacturers are getting a fair deal. Except for an abiding faith in the fairness of the American people, we all might well be discouraged. But we may well be assured that the rank and file of the people, when they get to understand conditions, will put aside all those who stand in the way of peace, happiness and prosperity in this great country, given to us as a heritage by those who fought for these principles many years ago. We should all, therefore, wait in patience for this change, which is as sure to come as day to follow night, and which may not be long delayed. We have in this country about one-sixteenth of the population of the world, and probably twenty or twenty-five per cent. of the wealth, and it seems to me no American can stand long before the public and wish to reverse these figures. (Applause.)

THE PRESIDENT: Is Uncle Joe Butler in the room? I do not see him. What is your pleasure, gentlemen?

(Cries of "Campbell," "Campbell.") Mr. Campbell is called for.

Mr. Campbell: Gentlemen, I thank you for the compliment of calling me, but you must remember I am one of the "old stagers," and I have often been called upon by the Judge, always to my great discomfort. I think the committee used such good judgment in selecting their speakers to-night, and they have turned out so well that I will not mar the proceedings by trying to say anything. You know Mr. King, he made an impromptu speech. Unfortunately I did not expect to be called upon, and I did not have mine written out. (Laughter and applause.)

The President: Speaking seriously, it is a great thing to have a little speech, however short, in your vest pocket in case you should be forced to say something. I should like to express my profound admiration for the ability which has been shown during this meeting by those who have presented papers, and by the speakers of this evening. Certainly we have reason to be proud of the talent connected with the American Iron and Steel Institute. Moreover, there has pervaded through the atmosphere of the day a sentiment which has made an impression and will have an influence of a decided character upon myself and upon all others I am sure. There is to be seen a feeling of friendship and kindly interest in each other, which, considered in connection with the ability possessed by the members of this Institute, is certain to secure results in the future satisfactory in every respect.

I may say for myself that my connection with this Institute has been not only gratifying but has been very happy. I am proud of the Institute, proud of my acquaintance with its members, and very grateful to all who have participated in the exercises of the Institute from time to time and who from day to day are doing so much to carry on the work of the Institute. It has been said during the evening that about all we have at the present time to encourage us in our business is hope for the future. I think we have more than that; we have expectation, and we are certain to realize our expectations. No one can tell just when prosperity may come, but that it is certain to come

none of us can have any doubt. This country is so great, our opportunities are so widespread, our natural advantages so remarkable, that it is not possible to long delay a return of prosperity and of profit in our lines of business.

Therefore, let us have courage and let us be patient, taking care of our interests, and, as I said this morning, trying in every way to help one another. Let us remember we cannot make anything for our individual selves by injuring any other person, and we cannot assist and benefit any of our neighbors or competitors in business without at the same time benefiting and assisting ourselves. If we even turn over tonnage to our competitor, it is only a question of time when he will turn over tonnage to us. If we do anything which is calculated to add to the treasury of our competitors in business, there is certain to be a return to us at least of like amount and probably a larger amount.

So, gentlemen, as suggested this evening, let us have sense, let us keep our heads, let us be cool and patient, and above all let us do everything we can to maintain and even to increase the affectionate feeling which we have towards each other and which is so pronounced during the exercises of this day.

Now, gentlemen, hoping for a return of prosperity, and that you may keep well, that you will succeed in your business and that you will all come to the next meeting, I bid you good night. (Great applause.)

OCTOBER MEETING

AMERICAN IRON AND STEEL INSTITUTE

SEVENTH GENERAL MEETING

Birmingham, October 29, 30, 31, 1914

The Seventh General Meeting of the American Iron and Steel Institute was held at the Hotel Tutwiler, Birmingham, Alabama, on Thursday, Friday and Saturday, October 29, 30 and 31, 1914.

On Thursday there were, as usual, three sessions, all held in the Tutwiler Ball Room. The forenoon session was devoted entirely to the reading of scientific papers and discussions, and the afternoon session to papers and discussions dealing with the iron and steel industry in the South. At the evening session, after the dinner, two papers were read, after which impromptu addresses were made by members at the call of President Gary.

The temporary office of the secretary, where members registered for the meeting and were provided with identification buttons and programs, was conveniently located opposite the elevator landing on the floor with and near to the Ball Room.

Friday and Saturday were devoted to seeing Birmingham and vicinity. On the forenoon and afternoon of Friday and the forenoon of Saturday the members of the Institute were guests of the Tennessee Coal, Iron and Railroad Company, going by special train to the principal mines and mills in the vicinity of Birmingham. A more extended account of the hospitalities enjoyed by the Institute during these two days will be found on pages 516 to 518.

The General Committee on Arrangements consisted of Messrs. James A. Farrell, Chairman; E. A. S. Clarke, John C. Maben, Charles M. Schwab, John A. Topping and Frank S. Witherbee. The Birmingham Committee consisted of Messrs. George G. Crawford, Chairman, and R. A. Brown, E. H. Cabaniss, Frank H. Crockard, John H. Kaul, H. K. Milner, Walker Percy, H. G. Seibels and T. O. Smith. To all of these gentlemen the Institute extends its very hearty thanks and congratulations.

FORENOON SESSION, 10:00 A.M.

Address by the President.............................ELBERT H. GARY

The Use of Steam Turbines for Various Purposes........FRANK G. CUTLER
Chief, Bureau of Steam Engineering, Tennessee Coal, Iron and Railroad Co., Birmingham, Ala.

Discussion.........................LEIF LEE AND KARL NIBECKER
Engineers, Youngstown Sheet and Tube Co., Youngstown, Ohio.

Discussion...............................ALEXANDER L. HOERR
Steam and Hydraulic Engineer, National Tube Co., McKeesport, Pa.

Discussion (submitted in writing)..................RICHARD H. RICE
General Electric Company, Lynn, Mass.

Summary.................................FRANK G. CUTLER

The Repair Department of a Modern Steel Plant.............JOHN HULST
Chief Mechanical Engineer, Carnegie Steel Company, Pittsburgh, Pa.

Discussion...............................BERTRAM D. QUARRIE
General Superintendent, Newburgh Works of American Steel and Wire Co., Cleveland, Ohio.

Discussion................................HOWARD L. BODWELL
Assistant District Manager, American Sheet & Tin Plate Company, Vandergrift, Pa.

The Use of Titaniferous Ores in the Blast Furnace.......FRANK E. BACHMAN
Blast Furnace Manager, MacIntyre Iron Company, Port Henry, N. Y.

Discussion.....................................ARTHUR H. LEE
Superintendent, Blast Furnaces, Lackawanna Steel Company, Buffalo, N. Y.

Discussion.....................................RICHARD H. LEE
Superintendent, Lebanon Furnaces, Pennsylvania Steel Company, Lebanon, Pa.

AFTERNOON SESSION, 2:00 P.M.

The Modern Development of the Iron and Steel Industry in the South
THOMAS K. GLENN
President, Atlanta Steel Company, Atlanta, Ga.

Discussion...............................GEORGE W. CONNORS
President, Connors-Weyman Steel Company, Birmingham, Ala.

Discussion.............................M. P. GENTRY HILLMAN
Carpenter & Hillman, Birmingham, Ala.

Southern Foundry Pig Iron.......................JAMES W. MCQUEEN
Vice-President, Sloss-Sheffield Steel & Iron Co., Birmingham, Ala.

Discussion..................................LUIS R. LEMOINE
President, United States Cast Iron Pipe & Foundry Company, Burlington, N. J.

Discussion...............................PASCHAL G. SHOOK
President, Birmingham Chamber of Commerce, Birmingham, Ala.

EVENING SESSION, 7:00 P.M.

DINNER

The History of the Iron and Steel Industry in the South.....JAMES BOWRON
President, Gulf States Steel Company, Birmingham, Ala.

Discussion............................HIRAM S. CHAMBERLAIN
President, Roane Iron Company, Chattanooga, Tenn.

Impromptu Remarks in response to call of the President

Remarks by the President...........................ELBERT H. GARY

ADDRESS OF THE PRESIDENT

Elbert H. Gary

Chairman, United States Steel Corporation, New York.

We may felicitate ourselves on the privilege of holding our convention within the confines of the beautiful city of Birmingham. The splendid achievements of the city during its forty years of growth excite our admiration; and the hospitable sentiment of her people which pervades the atmosphere enlists our gratitude. Highly appreciative of the traditional warmth and friendship of the people of the Sunny South for the stranger who enters within her gates, we are especially pleased to be the invited guests of this great city and to witness what has been and is being done to establish it as a great industrial metropolis.

The Work of the Institute Commended.

Everything I could say to you concerning the American Iron and Steel Institute and the work it is doing would be favorable. In the collection and distribution of statistics and other data relating to our industry it has been diligent, thorough, and efficient. It is generally recognized as a reliable source of information; and it may safely be predicted that its reputation in this respect will never be diminished. It is and will continue to be authority on all the questions within the domain of its inquiries, for it is recognized that its publications of facts may be depended upon. It will be in the future as it has been in the past the effort of those who are especially responsible for its management to conduct its affairs in such a way that it will be of assistance and benefit not only to its members but to all others who may be directly or indirectly interested in its work.

The value of the research concerning, and exposition of, the various subjects which are referred to in the papers, addresses and discussions presented at the meetings of the Institute from time to time might be dwelt upon at length.

The ability, learning and industry which have been displayed by the participants in these considerations have been striking and they evidence the fact that we have in our membership talents fully as good as any that may be found in this or any other country. What you shall have the pleasure of listening to during the day will be fully equal to that which has been presented at other meetings; higher praise could not be given.

Moreover, the feeling of business friendship between the members of the Institute from the time of its organization has not decreased, but is growing stronger and more deeply rooted as the years pass by. We are all proud to be considered honorable and worthy members. The Institute has before it a great future for service and results. Let us make it even better and more useful. It will be a power for good in the industrial world. The magnitude of the iron and steel industry in the years to come is probably beyond even the imagination. It is not too much to expect that this Institute will be one of the potential factors in the further development and utilization of the economic forces of this country which entitle her to be considered as a nation of commanding position and influence.

Business Not Now Prospering.

We are accustomed on occasions of this kind to refer to conditions of business. I am an optimist in principle as well as in practice. There is always a bright side, although it may be temporarily obscured. However, nothing is to be gained by closing our eyes to well-known and clearly recognized facts; and at present we are not very prosperous in our lines. This is reflected in the published reports of some of the larger companies. The President of one declares that "earnings from January 1st to October 1, 1914, on the tonnage produced have been at the smallest margin of profit since the formation of the Company." The report of another company shows that the income from manufacturing and operating, after deducting all incidental expenses, is less than one-seventh as much for the first nine months of 1914 as it was for the same

period of 1913. Still another sets forth that, for the first six months of 1914, the net earnings from operations were less than one-half of the amount realized for the same period of 1913. For the company last referred to I have no report since June 30, 1914. I do not refer to the results of the Steel Corporation nor to those of any other company because those of the former are extensively advertised from time to time, and are well known; and the reports of the others are not published at all, so far as I have been able to ascertain. It is sufficient to say at this time that the volume and prices of iron and steel sold in this country were very low, comparatively speaking, during the months immediately prior to the commencement of the European war; and with respect to the volume, there have been substantial decreases since that time. These facts are well known to all of you, and I would be doing an injustice if I were to assume that any of you was unfamiliar with them.

Confidence Based on National Resources.

But what of the future? What is there to encourage and stimulate us in our struggle for present existence and future success? It is well at all times to remember fundamental facts. At the semi-annual meeting of the Institute of October, 1913, there were given some figures in relation to the comparative wealth of the leading nations of the world. While they ought to be modified to some extent on account of the figures which have subsequently been published, still it is true that the enormous wealth of the United States is increasing and largely exceeds the wealth of any other country. And as an additional and important item it may be observed that of the eight and a half billion dollars of gold held throughout the world the United States is possessed of considerably more than one-fifth, if we may rely upon published statistics.

But of more consequence even, we are always comforted by the fact that the productive capacity and the actual production of wealth in the United States is growing year by year; and this ability to produce will not and cannot be diminished. Actual realization of profits may be

interrupted, but the great variety of its products and the length and breadth of its domains, with a climate and atmosphere unsurpassed, continuously serve to insure a certainty of increasing wealth and prosperity, and enables us to rely upon the ability of the nation to comfortably support her own inhabitants and to furnish a surplus to other nations in large and increasing quantities with corresponding returns in value. You are acquainted with the figures and realize the extent of our riches and the magnitude of our production. They are not referred to in a boastful spirit nor for any reason except one of encouragement for the future.

Besides at the present time the exports of a large variety of commodities are increasing, and although not equal to the volume reported just prior to the commencement of the war, yet much larger than it was immediately following the beginning of the war. This will have a material influence upon other lines. All are stimulated and brought into service. Without particularizing, it would seem safe to predict that in many important respects business conditions in the United States for the next three months at least will be better than they have been for the last three months.

Faith in the Long Future.

As to the long future I do not hesitate to say, with emphasis, that the opportunities for progress and success in this country are greater than ever before. If we can get out of the ruts of antagonisms, inconsistency, distrust, hypocrisy, individual indifference to the rights and interests of others, which seem to have prevented natural and legitimate progress during the last few years, so that the people generally will disregard undue personal ambition and will work together, joining hands for the protection and promotion of the welfare of all alike, having a disposition to utilize to the best advantage the privileges which this country affords, it will be only a question of time, and short at that, when the United States will be firmly established as the leading country of the world. Times and conditions are auspicious. The United States, with its vast

wealth and resources, should be the financial, industrial and commercial center of the world; and to a corresponding degree will be opportunities for worthy achievement in every direction. To the extent that we prosper legitimately and without prejudice to the rights or interests of others we may be able to render assistance to others who may need and are willing to accept it.

It is wise for all of us who are here to-day to place our faith in the wonderful possibilities of this country. In this connection, it is to be remembered there is a growing sentiment throughout the country in favor of just and fair treatment to all the people and all departments of human endeavor. There is a decided change for the better in this respect. Much has been said during the last few years in favor of according full attention to the rights of individuals, particularly those less fortunate in the contest to acquire the comforts of life; and this is right and must not be minimized nor interfered with; but in discussing these questions writers and speakers have sometimes been unreasonable in placing the blame for objectionable conditions. However, it now seems clear that in the future greater regard will be had for the rights and interests of all classes of the people without discrimination. Equal justice will be done to all, rich or poor, strong or weak. Politics or partisanship will not be used to obstruct the normal and legitimate growth of the country; and one of the most gratifying and encouraging signs of the times is the attitude of the leaders in public discussion and of the administrators of public affairs.

The International Meeting of 1911 in Europe.

About three years since a few of us had the privilege of meeting in Great Britain and Continental Europe the leading representatives of the iron and steel manufacturing interests of the world. For several days we were in close association with those men and became well acquainted with them and the spirit and motives which dominated their attitude and treatment of one another.

The countries represented included England, Scotland, Wales, Belgium, France, Germany, Austria, Italy, Russia, Spain, Hungary, Canada and the United States. All were pecuniarily interested in the iron and steel industry. All were active competitors, individual concerns of a single country with each other and each country with all other countries. While those engaged in many respective lines of manufacture were protected to a considerable extent against ruthless and destructive antagonisms by virtue of cartels or arrangements, recognized, if not fostered, by the chief authorities of their respective countries, yet there existed rivalry and competition which might, and at times no doubt did, produce feelings of envy and dissatisfaction. Nevertheless it was evident that a feeling of business friendship permeated the minds and influenced the conduct of these men, and this in the main tended to establish and uphold an orderly and profitable management of the affairs entrusted to them. And the disposition shown towards and the hospitality extended to the Americans by all others on this occasion secured for them our everlasting gratitude and esteem.

Those of us who were enabled to participate will never forget the incidents connected with our visit in England, Belgium and other places, or the disposition shown by every one to evidence his respect for and confidence in his rivals in business. Also, we remember, with grateful appreciation, the cordial reception given to us by the King of the Belgians, and the interest he manifested in the business welfare of the representatives of other nations. In passing, I will add that if the large numbers of business men who represented on this memorable occasion all of the countries engaged in the iron and steel industry could have had opportunity to consider and determine the questions leading up to the war which is raging in Europe there would have been no war. These intelligent, experienced, practical, sensible and Christian men, being from time to time in close contact, and therefore well acquainted with each other, would have been patient, considerate and fair-minded and would have made adjustments and reached conclusions calculated to protect

the interests of all and to prevent the possibility of the present deplorable hostility.

The Present War in Europe.

And because the subject attracts our attention and occupies our minds almost to the exclusion, for a portion of the time at least, of all other topics; and also for the purpose of making application to our own affairs, I ask your indulgence while I briefly refer to the cataclysm which envelopes a large portion of Europe and involves the lives and interests of hundreds of millions of people. We cannot think of this conflict without feelings of horror. It is impossible to realize the extent of the suffering and misery which it entails. If it should continue for eighteen months from the time of the commencement, the loss of life by reason of injuries received on the battle fields and sickness directly resulting from participation in the war will aggregate four millions in number; and the direct and indirect pecuniary loss to all the nations concerned will amount to thirty-five billion dollars. Indeed we will never be informed of the actual loss in lives or money which will result from this war. And after the war is ended what will be the consequences? Millions of widows and orphans bereft of protection or support; the loss of millions of dollars annually by reason of the deaths or crippled condition of soldiers whose productive capacity has been eliminated or decreased; nations groaning under the burden of taxation to pay interest on enormous national debts; pensions to survivors amounting annually to millions upon millions. The United States is still contributing $172,000,000 per annum for pensions and from this basis we may form some idea of the amounts that must be paid by the European nations. And more than anything else the anguish of mind on the part of survivors is something which cannot be described or measured.

Without attempting to locate the blame for the war, because the people of this country are disposed to maintain a position of strict neutrality, we may perhaps consider, though we would hesitate to do more than suggest

the possible cause or causes. We hear from those who advocate the settlement of international disputes by resort to force, many different reasons, some giving one reason and some another, which is believed in and insisted upon as sufficient. Wars have been influenced and prosecuted from motives of revenge for the perpetration of some wrong in the past, fancied or real; others for conquest of territory; others for commercial supremacy; others on account of religious questions; others for liberty of person or speech. Some go so far as to insist that when a country becomes thickly settled so as to tax the resources of the country in order to secure the necessities of life, it is justifiable to depopulate the country by deaths in battle; and still others that the destruction of a portion of the people in battle, particularly the weaker ones, is the only way to keep the people strong and healthy. It would be useless on this occasion to discuss these reasons, some of which at least must seem foolish to the average individual. There are many who claim to believe the present war is the outgrowth of a feeling of antagonism and animosity between the Slav and the Teuton. Others equally sincere believe it is a contest to secure additional territory. Without giving reasons in detail at the present time, I venture the opinion that the struggle for commercial supremacy was the underlying cause of the war, or at least had a decided influence upon its precipitation; that the questions at issue largely relate to dollars and cents. And many believe if representatives of the different nations had previously met in a spirit of friendly and considerate inquiry for the purpose of definitely and finally settling the financial interests of each, all trouble could have been averted.

If this be true, and I will assume it for the purpose of making a point later on, it may be inquired what will be the final result of the conflict? The nation that wins will surely lose, although this would seem at first blush a paradox. The enormous cost before mentioned and the long continued suffering on the part of the survivors will not be fully covered by any success or glory or indemnity. Before now every participant in the contest must realize

that it would have been better to have settled, if possible, all the existing differences, real or imaginary, and on a basis approved by some competent and impartial tribunal. The sums expended and to be expended by the different nations would have greatly extended their opportunities for success and happiness if wisely used for those purposes. Personally, I believe in a positive and binding agreement between all the nations for the final settlement by arbitration of all international disputes on a basis to be decided by a competent and impartial tribunal and for the enforcement of decisions by the nations not personally involved in the question at issue. Such an agreement could be made, such a tribunal could be permanently established and such an enforcement made practical if the nations were so disposed. These ideal conditions may never be brought about. Human nature is the same the world over. It is selfish and inconsiderate. Might too often makes right; the strong become arrogant, unreasonable and aggressive; the evil-minded are reckless and indifferent. I am not willing to admit that the majority of individuals are controlled by these infirmities. I think the average man is honest and fair-minded and desires to be just towards his neighbor; and that the world is growing better. I hope the time will come, even though not in my time, when wars and rumors of wars shall cease.

Lessons of War Applied to Business.

All that I have said applies forcibly to our business. We who are here to-day are engaged in competition; we are naturally selfish; we are often inconsiderate and indifferent. In representing the interests of those who place us in official position, we feel obligated to strive for success, and we go beyond reason or justice. As many of you have remarked at previous meetings, it was customary in the days gone by to harbor the same feelings and to pursue the same line of conduct in the iron and steel trade that have been exhibited in the European conflict. Business men struggled for revenge, or conquest, or suppression, or other reasons just as bad. The graves of concerns destroyed

were numerous; this has lately been testified to in open court by those who were familiar with the subject.

As bearing upon these conditions, I quote from an address made on a certain notable and well-remembered occasion by one of your number:

The old basic principle was based on a distrust of one's competitors; on the feeling that, to succeed yourself, you must crush your rivals; and on the solid belief that they were mean enough to feel the same toward you. As a result, every man went out knifing for his competitors; an industrial panic ran like wildfire. The smaller concern went down to ruin, and the stronger, which worried through to harbor, required financial experts to heal or to hide his wounds. No one benefited by this—all suffered, manufacturer and consumer alike.

To-day I congratulate you on your success in bringing about a new order of things in business. You have become well acquainted; you have confidence in each other; you believe what is told you; you recognize the interests of your neighbor; you are glad when he prospers and equally sorry when he fails of success. You have a better and clearer understanding of business obligations. You can faithfully represent your stockholders, or the owners of your properties and indulge in the keenest competition, without doing anything that is destructive and oppressive, or unfair.

I quote further from the speech already referred to:

A voice rang strong and clear: 'Steady, boys, and play the game.' And by the Lord you played, and played it fair.

And from another speech on the same occasion:

The real test of friendship is in adversity. It has enlarged our horizon and given us such a broad and clear view of duty and opportunity, that we have been able, without the sacrifice of any fundamental principle, to change and avoid much that was undesirable and costly in the old time business methods.

It is true that the law of supply and demand still governs the output, and that we still have competition, but it is reasonable competition.

It is certain that we have much to be thankful for in

this delightful gathering that marks the era of friendship and good-fellowship, which has gradually but surely taken possession of us even against our will. We have gotten the habit of considering our neighbor, and of putting a value on his good opinion. It is a decent habit and a great asset.

And from another speech:

The broad principles that have been brought into this business were new. Their effect was marvelous, their success unquestioned. It was a renaissance and a newness of things that were necessary and invigorating.

And from another:

The iron and steel manufacturers of this country stand on a higher, broader and fairer basis of business relationship.

Some Principles of This Institute.

This Institute at the outset adopted, by tacit consent at least, as one of its principles, the following sentiment:

Real, hearty, cheerful and continued co-operation on the part of the members will secure results which should be entirely satisfactory. Frank and friendly intercourse; full disclosure of his business by each to the other; recognition by all of the rights of each; a disposition to assist and benefit each other so far as practicable and proper; conduct founded on the belief that healthy competition is wiser and better than destructive competition.

And so I trust that in all our deliberations we bear these principles in mind. Commercial warfare, which means destruction and oppression, should be as distasteful as the battles which kill and maim the soldiers, for they are the same in pecuniary results. They are injurious to all of those who are engaged and they seriously distress those who may be dependent upon the concerns which are eliminated. Without taking more time to further discuss these questions, I suggest that it is to the benefit and interest of all of us to have each one of those engaged in competition proportionately successful with all others; and that by all fair, honorable and proper means we should encourage these conditions. Undoubtedly it would be to the best interests

of all the nations engaged in the present war, and indeed the world at large, if the integrity and geographical lines of each of these nations could be substantially preserved. Do not think by this I am intending to express any opinion in regard to the merits of this unfortunate controversy. I mean only to say that it is well for the world at large to have honest, active, keen and successful competition; and it is unhealthy and distasteful to have national conditions which lead to destruction or oppression of rivals in trade. This is equally true of individuals, including ourselves.

One of the fundamental principles of this Institute is comprehended by the words "conciliation" and "co-operation." This should never be abandoned or modified. It should be extended to every branch of our activities. Nothing is to be gained and much is to be lost by antagonisms. Communities succeed or fail together. Competitors in trade, producer and consumer, employer and employee, the private individual and the public—all secure the best results if they work together. The success of one on legitimate lines means the benefit of all, and the failure of one means loss to all. The more we consider these questions, the more clearly we realize that what I have said is true. But the unreasonable critic or agitator is the enemy of mankind, including himself. He obstructs and destroys and he does not create or improve. One who is controlled by selfish, unfair, or dishonest motives—even though he may secure a temporary advantage—will never receive any lasting benefit. This applies to all classes of people and to every department of life. It applies to us in considering our attitude and conduct towards others, and, with equal force, to those whose action or disposition affects us. If we are sincere and fair in our treatment of others we may hope for similar treatment by them. If we are diligent in trying to ascertain the good in others they may see some good in us. The members of this Institute will do their full share in the general endeavor to add to the material and moral strength and growth of the nation. (Applause.)

The President: Mr. Frank G. Cutler.

THE USE OF TURBINES FOR VARIOUS PURPOSES

Frank G. Cutler
Chief, Bureau of Steam Engineering, Tennessee Coal, Iron and Railroad Company, Ensley, Ala.

For some years past there have been few radical changes effected in the process of manufacture of Iron and Steel and the attention of the managers has been largely directed to improvement of organization to increase the efficiency of labor and the reduction of operating costs, so that while the selling price of almost every other article of commerce is greater, and while the cost of labor is higher, it has been possible to maintain or lower the unit selling price of iron and steel products.

In hardly any other way has the reduction of operating costs been excelled at least in relative values than by the lowering of power costs and the saving effected by displacement of labor made possible by cheaper power.

This has been done by several methods; for example, the installation of gas-engine-driven blowing engines and gas-engine-driven generators, motors on rolling mills to displace engines (which must necessarily have had sufficient capacity to handle the maximum load and thus have been operating generally at an uneconomical load), together with the elimination of their attendant standby losses; also by the connecting of boiler houses by steam lines to utilize excess furnace gas and allow the shutting down of uneconomical boilers and the operation of boilers at a more economical load.

Other examples are the installation of condensers on non-condensing units, and improvements in economy of existing units by installation of apparatus of higher economy, such as low or mixed pressure turbines. By the term mixed pressure turbines is meant a turbine that will take either low pressure or high pressure steam or both.

Reduction of Power Cost at Ensley.

A striking example of the possibilities of the last mentioned plan is afforded by the Ensley Plant of the Tennessee

Coal, Iron and Railroad Company. At the time of its acquisition by the Corporation, this plant (consisting of six blast furnaces, eleven open hearth furnaces, a blooming mill and rail mill, and shops) had seven boiler houses and two electric power stations, with a total rated capacity of 1,800 K.W. and a third power station of 1,800 K.W. capacity had just been completed. All of the engines in the plant operated non-condensing, and no power was supplied to the outside plants. Additional electric power was required for various purposes and the enlargement of the blast furnaces consequent to changing them from hand-filled furnaces to skip-filled furnaces taxed the blowing engines, so that it was found advisable to materially increase the blowing capacity at the blast furnaces.

A saving in steam requirements might have been obtained at the mill by the installation of compound condensing mill engines and the steam saved applied to the generation of additional power, but this involved the displacement of practically new equipment, which was ample for the work under non-condensing conditions. Also, at the blast furnaces, a new boiler house of 16,000 H.P. capacity together with another plant of 6,500 H.P., the fact that the blowing engines were comparatively new, as well as certain conditions connected with water supply, practically committed this plant to steam-driven apparatus.

All of this original apparatus having been operated non-condensing, low pressure turbines were of particular advantage to the plant in that no change in engine conditions was necessary.

By the installation of low pressure turbo generators with condensers and cooling towers, installation of low pressure turbo blowers with condensers and cooling towers at the blast furnace blowing engine house, two boiler plants have been dismantled, another at the local pumping station only operates occasionally, and two more at the steel plant are only operated during the time the mills are rolling, being shut down over Sunday, during which period the furnace boilers supply all the steam. Also all electric power is supplied for the operation of the American Steel & Wire plant

at Fairfield; the By-Product plant of the company at Fairfield; and all electric power required for operation of seven coal mines of the company in the neighborhood of Ensley; resulting in the shutting down of several boiler plants, and reduction in load of others. Besides this a street railway line (The Birmingham, Ensley & Bessemer) is also supplied with all power required for the operation of 25 cars on 32 miles of single track.

This has been accompanied by an increase of product and a reduction in coal consumption, and the general result can probably be best shown by the statement that the saving in coal with present equipment and methods of operating over former practice, is estimated to be at the rate of 200,000 tons per annum.

Low Pressure Turbine Installations at Ensley.

Inasmuch as this is perhaps the largest equipment of low pressure turbines in a steel plant in the country, it will be in order to briefly describe the equipment and discuss the results obtained.

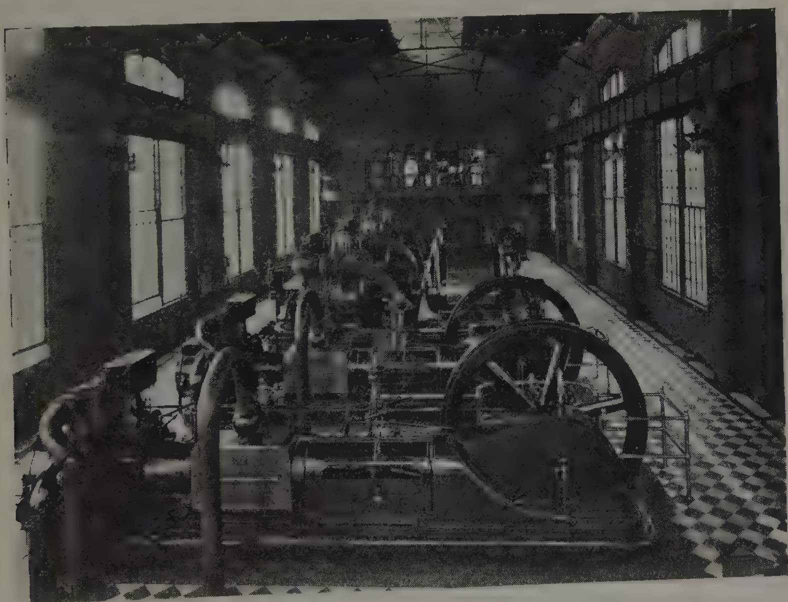


Fig. 1.—No. 2 Power House, Ensley. Three 3,000-K.W. Mixed Pressure Turbo Generators.

In the No. 2 Power House adjacent to the rail mill are three 3,000 K.W., 25 cycle, 3 phase, 6,600 volt generators operating at 1,500 R.P.M. and driven by mixed pressure turbines which are supplied with exhaust steam through five regenerators, each 8′ diameter by 50′ long from two 55″ ×66″ twin reversing engines, one driving the 44″ blooming mill and one driving the 34″ roughing rolls, and a 52″×72″

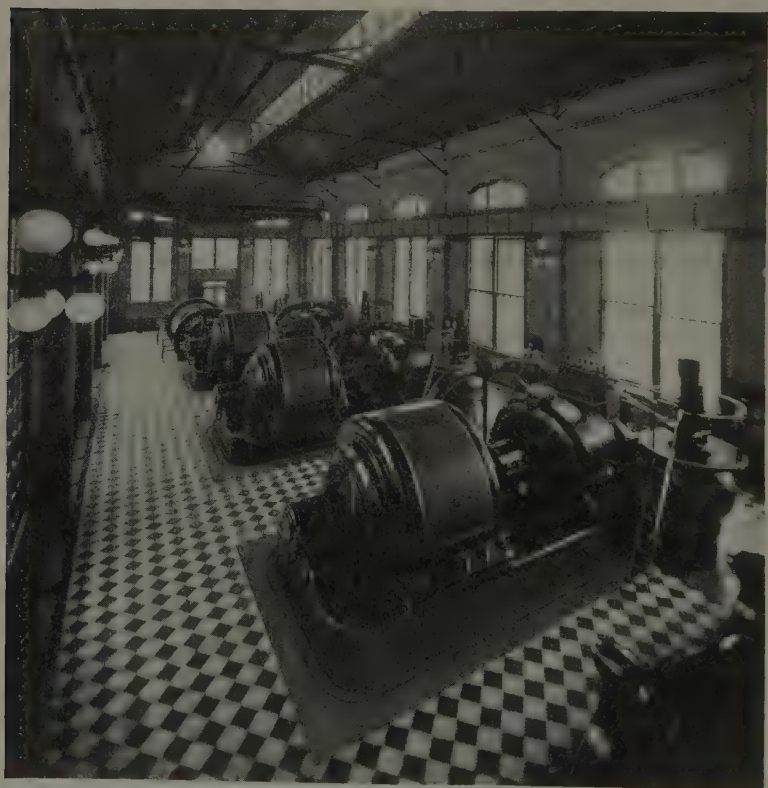


FIG. 2.—No. 2 Power House, Ensley, from Switchboard Gallery.

Corliss engine driving the 28″ finishing rolls. Steam from the pressure pumps and air compressor (after the feed water heaters are supplied) is also utilized for power.

The capacity of these regenerators is sufficient to absorb the extreme fluctuations in steam delivery as evidenced by the fact that under certain power conditions requiring the

use of all available low pressure steam, there will be no loss of exhaust steam at the back pressure valves over long periods. This is accomplished without raising the back pressure on the engines over about four pounds. The 44″ mill is one of the fastest blooming mills in the country, having a 24-hour record of 2,848 tons and a monthly record of 61,184 tons, both of these records being made in April, 1913.

The diagrams given below (see Chart I.) were obtained by a special recording apparatus consisting of a chart moved

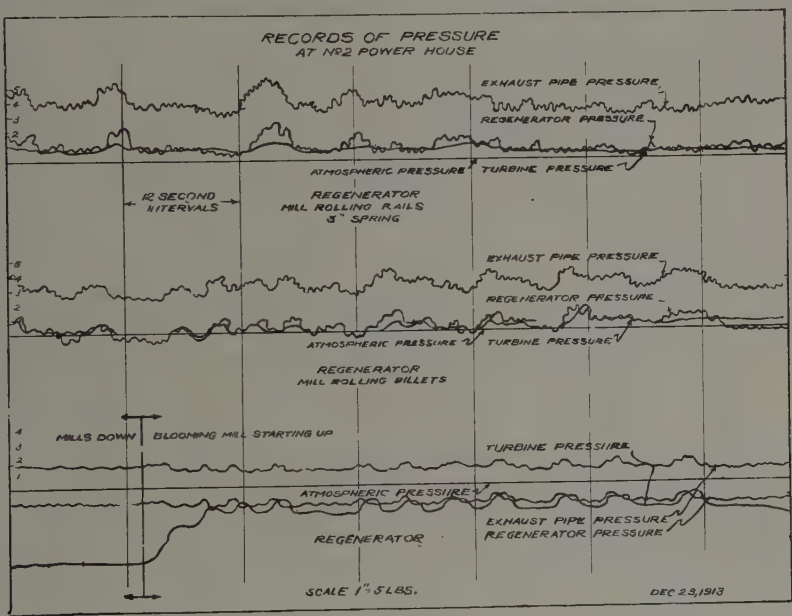


Chart I.

by a small motor at constant speed using three steam indicators with light spring, one showing the variation in pressure in the exhaust line from the engines leading to the regenerators, a second connected to the regenerator steam space, and the third connected to the low pressure supply line to the turbines, the relief valve on the regenerator blowing at about four pounds gage. The top diagram was obtained when the mill was rolling rails at maximum rate, the middle diagram when only the two reversing engines

were operating and the lower diagram when the mills were starting up after a shut-down period. The wave-like fluctuations in pressure in the turbine supply line to the left each show the effect of one pass in the blooming mill.

At the No. 1 Power House, which is located near the blast furnaces, are three Corliss engines driving 600 K.W., 2,200 volt generators and one Corliss engine driving a 2,000 K.W., 6,600 volt generator, the exhaust of these reciprocating engines being connected to a 3,000 K.W. mixed pressure turbine similar to the three units in No. 2 Power House, no regenerator being necessary on account of the relatively steady load. These two stations are operated in parallel and the load is divided between the two stations according to steam conditions.

Turbo-Blowers at the Blast Furnaces.

The turbo-blower equipment at the blast furnace is located in two blowing engine houses, two mixed pressure turbo-blowers each of 55,000 cu. ft. per minute capacity, being located in a new building adjacent to the No. 1 Blowing Engine House, taking exhaust steam from sixteen long crosshead type vertical reciprocating blowing engines, the air tubs of which have Corliss inlet valves and poppet discharge valves and one mixed pressure turbine-driven blower of 45,000 cu. ft. per minute capacity located inside the No. 2 Blowing Engine House, taking steam from seven similar blowing engines. The last mentioned turbo-blower was originally a high pressure turbine-driven machine, located temporarily outside the same building and was put into operation during December, 1912, on No. 4 Blast Furnace (of 350 tons nominal capacity) which had just been relined. The operation of this furnace for the year 1913 with respect to apparent blast conditions, as shown by the accompanying graphical tabulation of records, is interesting. (See Chart II., next page.)

In this compilation the blast delivery of the turbo-blower was obtained by recording the average setting of the scale beam on the constant volume governor, by which the speed of the turbine is controlled, and the delivery of the engines

was obtained by using a figure of 365 cu. ft. of air per revolution of an 84″ by 60″ tub, the displacement of which was 383 cu. ft., this figure making an allowance of about

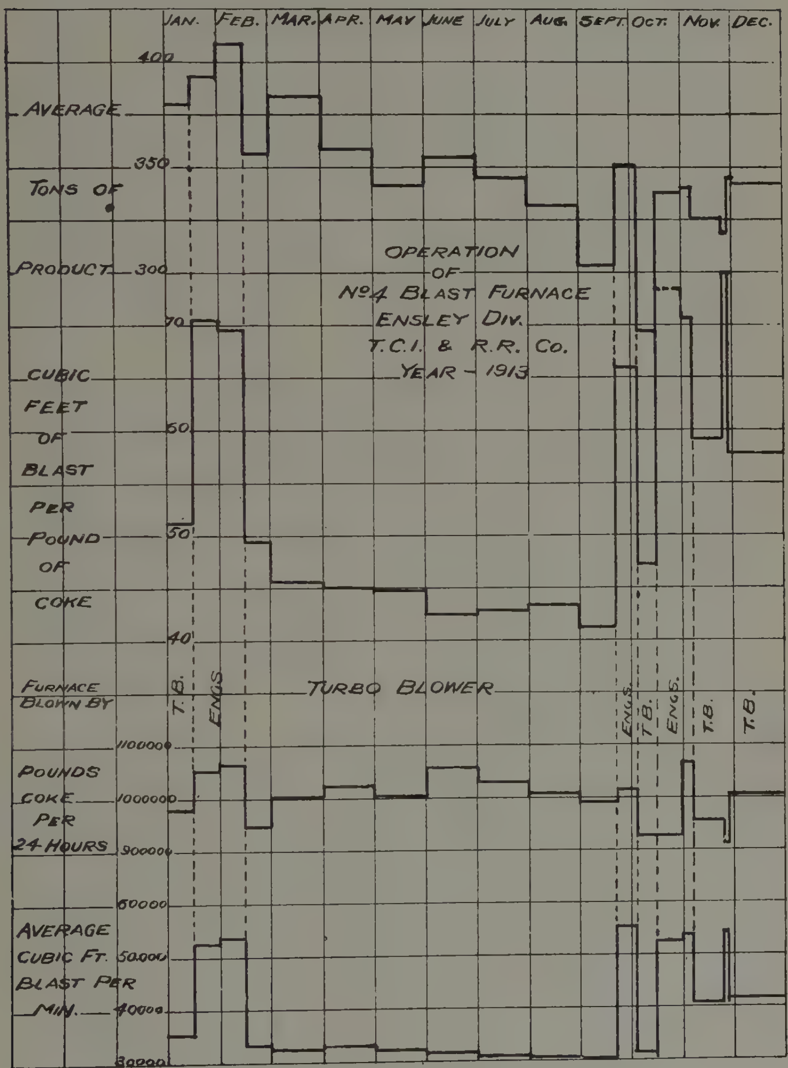


CHART II.

5 per cent. for induction loss and expansion of air in the clearance, this being the apparent delivery as derived from a number of indicator cards. No allowance was made for

leakage in the cold blast line, stoves or furnace. As No. 4 furnace was blown through a new double riveted cold blast line and the stoves and furnace had just been repaired, the leakage in furnace connections during this period was believed to be small.

The ratio of the blast delivered by the engine (or blower) to the furnace per pound of coke burned, is used by the blast furnace men as an indication of furnace and engine leakage, since with the same burden and coke quality any increase in apparent blast generally indicates leakage and it is usually considered that it takes about 50 cu. ft. blast in the furnace to burn one pound of coke, this figure varying somewhat with the burden.

Tests to Determine Blower Delivery.

By the examination of the graphical log of operation of No. 4 furnace a great difference in this figure for blower operation and engine operation is apparent, and in order to reconcile the apparent discrepancy a series of tests was made during the latter part of 1913 to determine the actual delivery of the blower. Some of the difference was found to be due to an accumulation of dirt on the constant volume governor which increased its weight, thereby changing the effective setting of the scale beam.

The tests were made by disconnecting the blower from the blast line and installing one nozzle of $11\frac{1}{4}''$ nominal diameter on the discharge of the blower and one nozzle $24''$ nominal diameter on the suction pipe of the blower. The formula used was derived from the general formula for flow of gas through Venturi meters as follows:

$$W = Fm\ (pn\ Yn)^{\frac{1}{2}} \left(\frac{2gK}{K-1}\right)^{\frac{1}{2}} \left(\frac{Pm}{Pn}\right)^{\frac{1}{K}} \left[\frac{1-\left(\frac{Pm}{Pn}\right)^{\frac{K-1}{K}}}{1-R^2\left(\frac{Pm}{Pn}\right)^{\frac{2}{K}}}\right]^{\frac{1}{2}}$$

where W = weight of gas in pounds per second.

Fm = Area of throat of Venturi meter (or nozzle) in sq. ft.

Pm = Absolute pressure in throat lbs. per sq. in.

Pn = Absolute pressure in upstream section lbs. per sq. in.

pn = Absolute pressure in upstream section lbs. per sq. ft.

Yn = Weight of gas in lbs. per cu. ft. in upstream section.

$$K = \text{Ratio } \frac{\text{Specific heat at constant pressure}}{\text{Specific heat at constant volume}} = 1.405 \text{ for air.}$$

$$R = \frac{Fm}{Fn} \text{ Ratio of area of throat and upstream sections.}$$

Also as we desire the flow in cu. ft. per minute under standard conditions.

$$Q = \text{Cu. ft. min.} = \frac{60\ W}{Yo} C$$ where C is the co-efficient of the meter or nozzle (taken as .99).

Yo = the weight per cu. ft. of air at standard conditions (.0763).

By the assumption that for flow through a nozzle from atmosphere into a pipe, or where an impact tube is used to measure the upstream pressure in a closed pipe leading to the nozzle; R in the above formula becomes zero, and

$$Q = \frac{Fm\ Pm}{\sqrt{Tn}} \sqrt{A(A+1)} \text{ where } A = \left(\frac{Pn}{Pm}\right)^{.288} - 1$$

This formula is similar to that given on pp. 1111 Trans. A. S. M. E., July, 1913.

The calculation of flow by the above formula showed the delivery by nozzle measurement on the suction pipe exceeding that on the discharge pipe by about 1.8 per cent. for several different tests with volumes varying from 30,000 to 48,000 cu. ft. per min. Some of this difference can be accounted for by a leaking joint at the discharge nozzle which it was not found possible to stop during the tests.

After changing the calibration of the scale to agree with the nozzle test the turbo blower was put back on the furnace. The average operating records for a period of fifteen days

prior to and for fifteen days after putting the turbo blower back on the furnace are given below:

	October 23 to November 6, inclusive	November 8 to November 22, inclusive
Furnace blown by	Engines	Blower
Average product	344	321
Cu. ft. of blast per minute	52,415	40,700
Blast pressure	13.50	17.85
Pounds coke consumed per 24 hours	1,036,000	951,000
Cu. ft. blast per pound coke	70.5	59.5
Pound coke per ton product	3,012	2,952

Since the furnace conditions were not appreciably changed it will be seen from the above that the equivalent delivery of the blowing engines per revolution was about $\frac{59.5}{70.5} \times 365 = 307.5$ cu. ft., indicating an efficiency of delivery of the tubs of 84.4 per cent. or, since the displacement of the air tub was 383 cu. ft. per revolution, the ratio of the actual delivery to displacement was about 80.2 per cent.

Similar comparisons were made for other periods for the two turbo blowers at No. 1 Engine House and it was decided to make tests on these blowers by the installation of a nozzle on the cold blast line.

On "A" Blower this nozzle was installed at the north end of No. 1 Blowing Engine House at the end of a new 42″ main about 450 ft. long, the nozzle throat being 19.7″ in diameter. As all furnaces were in operation and as there was no valve near the nozzle end of the line that could be shut, it was impossible to make a leakage test on the main, but observations made of the manometers on the nozzle prior to and after the test showed no flow, indicating no leakage into the main through gate valves from the blast lines of other furnaces under blast. On "B" Blower this nozzle was installed at the south end of No. 1 Blowing Engine House on a section of pipe connected to eight vertical blowing engines and through a new section of pipe to this blower, similar conditions preventing a leakage test on the main, although there was no leakage into this section

of the main from engines or other cold blast mains. Also during the tests on the blowers the pressure was controlled by throttling valves near the blowers, so that the pressure on the mains was only a few ounces above atmosphere.

After the test on "B" Blower was completed three of the blowing engines were run on this main blowing through the nozzle, at an average speed of 44.3 R.P.M. each. On account of the impossibility of placing a valve between this main and the nozzle it was necessary to throttle the indi-

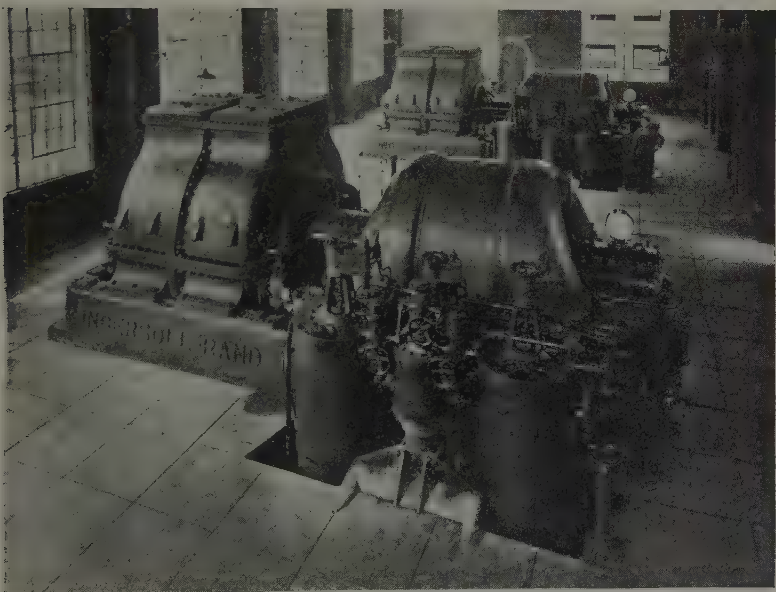


Fig. 3.—No. 1 Turbo Blower House, Ensley. Two 55,000 Cubic Feet Capacity Mixed Pressure Turbo Blowers.

vidual valves at the blowing tubs to raise the blast pressure in the blowing tubs, and as the volumetric capacity of the air connections was limited it was not found advisable to raise the average tub discharge pressure above ten pounds on account of the wide fluctuation in pressure and delivery through this throttled valve On this account the leakage and slip of the blowing tubs is lower than would have been the case had it been possible to carry the usual discharge pressure on the tubs. The principal data and results of

these tests, which were made August 8th and 9th of this year, are given in the following table, the apparent blast for the blower being obtained from mercury column on the Venturi meter on the suction pipe, which is the constant volume governor for these turbo-blowers, and by multiplying the R.P.M. of the engines by 365 for the test of engines.

	Turbo A.	Turbo A.	Turbo B.	Turbo B.	Turbo B.	Engine
Apparent blast, cu. ft. per minute	27,960	42,300	30,630	39,920	44,930	48,500
R.P.M. blower or engines	2,054	2,470	1,934	2,410	2,691	133
Blast pressure per sq. in., pounds	10.78	14.96	9.60	15.2	19.86	10.0
Orifice temperature, deg. F	146.0	183.4	152.8	197.2	233.7	184.6
Inlet temperature, deg. F	80	80	76	76	77	78
Orifice static pressure, inches H_2O	17.25	42.0	23.37	41.5	62.50	37.0
Orifice impact pressure, in. H_2O	18.00	43.0	24.50	43.75	64.62	38.00
Atmospheric pressure (Pm.), pounds per sq. in.	14.46	14.46	14.46	14.46	14.46	14.46
Cu. ft. blast per min., Standard Conditions	31,887	48,190	37,350	48,350	56,730	45,085
Cu. ft. blower conditions	33,500	50,650	38,950	50,400	59,200	47,150
Ratio $\left\{ \begin{array}{l} \text{actual blast} \\ \text{apparent blast} \end{array} \right\}$	1.141	1.138	1.218	1.212	1.262	0.93

For the first two of the above tests, these on A Blower, it was possible to measure the low pressure steam consumption of the turbo-blower by means of a heat balance on the condenser, as no other apparatus exhausted into the condenser, and the governing mechanism was arranged so that no high pressure steam was used on this machine during the tests.

The results of the calculations for the second test on "A" Blower obtained by this method are given in the following table, the heat accounted for being the sum of the heat rejected to the condenser (pounds injection water per hour × temperature rise), heat radiated (sq. ft. surface × mean temperature difference × 2.7) and heat utilized in work (H.P. required to compress air ÷ assumed efficiency of blower × 2,545). The sums of the above is divided by the heat available in one pound of low pressure steam, above hot well temperature, proper correction being made for quality of low pressure steam as shown by calorimeter.

For the above test these figures follow:

Heat rejected to condenser per hour, 4,500,000 pounds × (114 −95) B.T.U.	85,500,000
Heat utilized in work, $48{,}190 \times .04991 \times \frac{2{,}545}{.70}$	8,740,000
Heat radiated (1,120 ft. × 33) + (600 ft. × 128) × 2.7 B.T.U.	310,000
Heat accounted for total	94,550,000

Low pressure steam-pressure in pounds per sq. in. gage	2.8
Vacuum corrected for barometer	26.64
Quality low pressure steam to turbine	97.5%
Heat per pound exhaust steam above hot well in B.T.U.	1,047.2
Total exhaust steam per hour to turbine, pounds	90,300
Equivalent dry steam per hour to turbine, pounds	88,650
Brake horsepower at 70% efficiency	3,435
Pounds exhaust steam per brake horsepower hour	25.80
Cu. ft. blast per minute (standard conditions)	48,190
Blast pressure, pounds per sq. in.	14.96
Equivalent cu. ft. blast per min. against 15 pounds	48,105
Pounds dry exhaust steam per minute	1,477
Pounds exhaust steam per 100 cu. ft. blast at 15 pounds	3.07

As the steam consumption of an engine according to the Rankine Cycle under the above steam conditions is 17.26 pounds per H.P., the above test shows a heat efficiency referred to the Rankine Cycle of 67 per cent. This latter figure would be lower if the efficiency of the blower is higher than the 70 per cent. which was assumed in order to obtain the heat balance. This efficiency is no doubt higher at greater loads.

Steam Consumption Tests.

In order to check the steam saving by installation of turbo-blowers, it is necessary to know the consumption of the original equipment, and a similar test was made on five blowing engines at No. 2 Blowing Engine House by shutting down the turbine-driven centrifugal pumps that ordinarily exhaust to the condenser and supplying the condenser temporarily with water from the blast furnace system. The principal data of this test are given below, the actual blast delivery being taken as 307.5 cu. ft. per revolution as shown by previous calculations, the indicated horsepower however being based on indicator card results.

Heat Balance Test: Steam Consumption of Blowing Engines.

	R.P.M.	Blast Pressure Pounds	Cu. Ft. Blast at 307.5 per Revolution
Engine No. 20	35.2	15.81	10,825
Engine No. 22	41.7	15.81	12,830
Engine No. 23	43.4	11.11	13,350
Engine No. 24	35.4	11.11	10,890
Engine No. 25	32.3	11.11	9,940
Total	188.0		57,835
Total cu. ft. blast against	....	15.81	23,655
Total cu. ft. blast against	.....	11.11	34,180

Indicated horsepower	3,473
Heat equivalent of work per hour I.H.P. x 2,545	8,838,000
Radiation	49,500
Heat rejected above hot well temperature, 2,000,000 pounds x (114.5—83)	63,000,000
Steam 142.7-pound gauge vacuum, 26.51 in. Quality, 98.5 per cent. Heat per pound above hot well temperature B.T.U.	1,098.5
Pounds steam supplied engines per hour	65,435
Dry steam supplied engines per hour	64,450
Pounds steam per I.H.P., steam cylinders	18.5
Blast per min. at 15 pounds (23,655 x 1.01418) + (34,180 x .7855) cu. ft	51,500
Steam per 100 cu. ft. at 15 pounds = 2.09 pounds.	

The steam consumption of 2.09 lbs. per 100 cu. ft. of actual blast corresponds to 18.5 lbs. per I.H.P. hour. When operating non-condensing against 2 lbs. back pressure the steam per 100 cu. ft. of blast at 15 lbs. is about 3 lbs. corresponding to a gross saving of 30 per cent. by condensing these blowing engines.

The latent heat in one pound of exhaust steam at 26.5″ vacuum is 1024.4 B.T.U., and as approximately 957 B.T.U. per pound of steam is given to the condensing water, the quality of the engine exhaust to the condenser in the above tests was about 93.4 per cent. The use of three pounds steam per 100 cu. ft. of blast corresponds to 27 lbs. steam per I.H.P., this figure being checked by tests of the steam plants in the past, which gives an efficiency as compared with the Rankine Cycle of 54.5 per cent. and by the use of Molier diagram the quality of exhaust steam from these non-condensing engines is found to be about 95 per cent.

On this basis, 3 lbs. of dry steam delivered to engines per 100 cu. ft. of blast, would furnish 2.85 lbs. dry exhaust steam, which in the turbo blower would blow $\frac{2.85}{307} \times 100 = 93$ cu. ft. of blast; both engines and blower delivering against 15 lbs. blast pressure.

Saving from Use of Turbo Blowers.

With blowing engines operating non-condensing as was formerly the case at Ensley, a 30 per cent. saving in steam prime movers was made by condensing; and by operating the same engines non-condensing, and utilizing the exhaust steam in low pressure turbo blowers, a gross saving over original non-condensing conditions of about 93 per cent. was made; making the saving by installation of turbo blowers over condensing operation about 48 per cent. Local conditions requiring the use of cooling towers modify these figures somewhat, although the relative saving is not greatly different.

Fig. 4.—No. 2 Power House Cooling Tower, Ensley. Capacity 18,000 Gallons per minute.

Water for condensing purposes during the second test on "A" turbo blower was obtained from cooling towers at a temperature of 95 degrees, so that it was hardly possible to materially improve the vacuum of 26.64″ during the tests, as the difference in temperature between the hot well and temperature corresponding to vacuum was 5 degrees. With 28″ vacuum, which it is possible to maintain with 75 degrees injection water, which is available during the winter, the steam consumption of the low pressure turbine would be improved at least 16 per cent., reducing the steam per 100 cu. ft. blast to 2.65 lbs. This means that from the exhaust steam of reciprocating non-condensing blowing engines into turbo blowers which in turn exhaust into condensers at 28″ vacuum, the actual blast delivery of these engines would be increased by 113 per cent. For an average vacuum of 27.3″ the actual blast delivery is practically double that of the non-condensing engines. In other words, from the steam used to blow three blast furnaces with high pressure non-condensing engines, three additional furnaces are blown by means of low pressure turbo blowers and condensing equipment.

The term "blast unit" which is the blowing of 1,606,140 cu. ft. of blast against 15 lbs. pressure has been used as a unit of delivered power of blowing engines, and is the equivalent of the generation of 1,000 K.W. hours. To generate a blast unit with Ensley apparatus would require $\frac{1,606,140}{193}$ x 3 x 25,000 lbs. of live steam, which at the cost of steam (including labor, coal and credit for gas) of about 10 cents per 1,000 lbs., represents a cost per blast unit of $2.50, and is equivalent to a steam cost of one-quarter of a cent per K.W. hour.

By the original method of blowing these furnaces by non-condensing engines 48,180 lbs. of live steam were required per blast unit on the same basis. It should be noted here that these figures are for actual blast and for comparison with usual figures for displacement measurement, would have to be reduced from 10 to 15 per cent.

Also by the operation of these blowers we have been able

to put more reciprocating blowing engines on other furnaces, thereby materially reducing the cost of repairs by operation at lower speed. One man operates one blower ordinarily having nothing to do but to check the furnaces on signal by operation of a small hand wheel. The total blowing cost is materially lower.

It is reasonable to believe that the ability to maintain the volume of air supplied to the blast furnace constant would tend to more regular and consequently more economical operation, but so far as has been definitely deter-

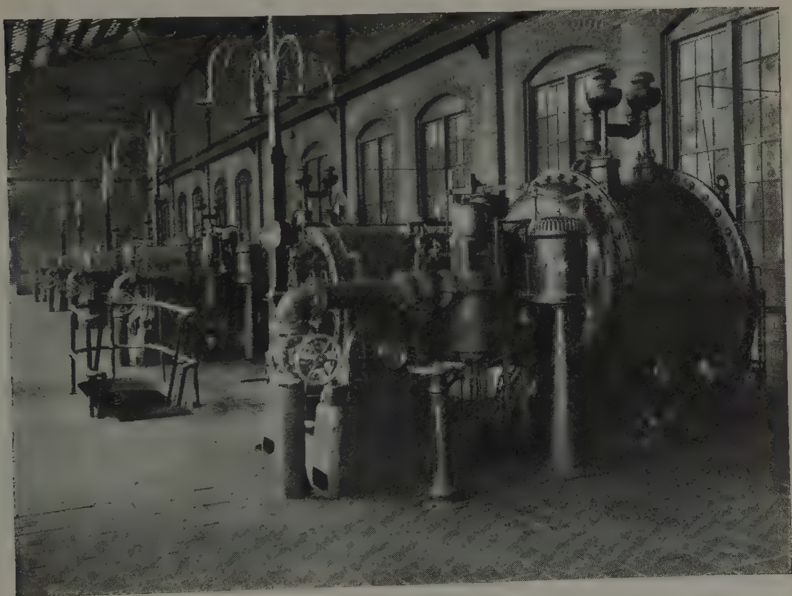


FIG 5.—Exhauster Room, By-Product Plant. Five Gas Exhausters, each of 9,000,000 cubic feet in 24 hours.

mined by us, there has been no great difference in the operation of blast furnaces by means of turbo blowers as compared with reciprocating engines, with the exception that after a stop or check on the furnace, full delivery is obtained more quickly than with engines.

USE OF TURBINES IN OTHER OPERATIONS.

The operation of turbo-blowers and exhausters in by-product work is a comparatively recent service and the

Tennessee Company was the first to install them in this country and probably the first anywhere to use them exclusively.

At the By-Product Plant at Fairfield there are five two-stage exhausters driven by three-stage high pressure turbines, each of 9,000,000 cu. ft. capacity in twenty-four hours, that pull the gas from the batteries through the cooling apparatus and deliver the gas through the tar extractors to the saturators. Also at this plant there are two three-stage high pressure turbo-driven boosters, one of 24,000,000 cu.

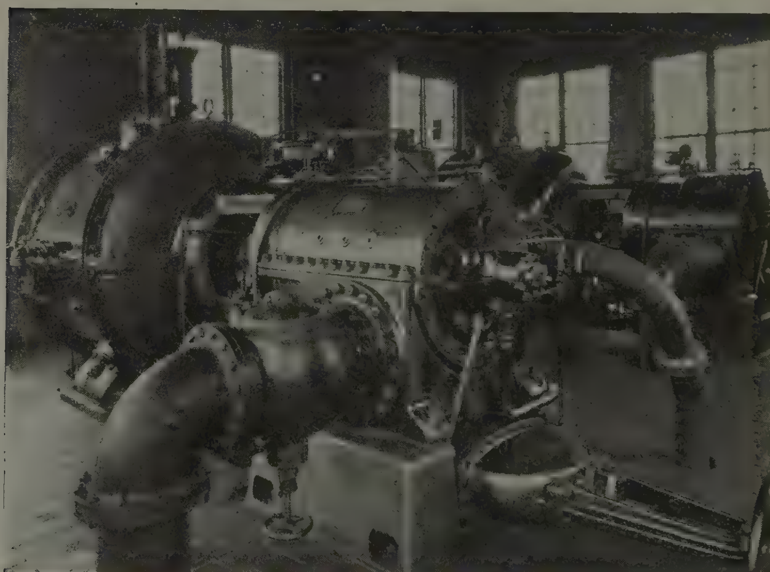


FIG. 6.—Booster Station By-Product Plant. Two Turbine Driven Gas Blowers.

ft. and one of 28,000,000 cu. ft. capacity, one operating at a time, and delivering surplus gas through a 24″ line to the Ensley Steel Plant.

With the usual type of apparatus a much larger by-product building and heavier foundations would have been required, and the experience of nearly three years' operation has justified the claim that this type of apparatus has a lower operating cost for labor, repairs and lubricants, as well as steam; and with the exception of trouble with shaft packing

due to action of gas on the metal used originally, the installation has been successful in every way. There is a peculiar advantage in the use of turbo exhausters in by-product service in that the centrifugal action of the blower throws out the small particles of tar or tar fog carried with the gas, almost eliminating the work required of the tar extractors, which are located between the exhausters and the saturators. 3 per cent. of the total tar production of the plant is recovered from the drains on the turbo exhausters.

The speed and delivery of both boosters and exhausters is controlled by a float attached to the governor, the position of this float being determined by the suction pressure, so that the suction pressure is maintained practically constant although the delivery pressure, gas volume and speed are variable.

The use of turbine-driven centrifugal pumps for condensers' service is usual, and there are at Ensley some eighteen centrifugal pumps delivering water to condensers and cooling towers driven by turbines.

When it is considered that the turbine is a comparatively recent development, particularly in the Steel Industry, practically no turbines having been installed ten years ago, the conservativism of the usual manager to their purchase and the prejudice of the operators accustomed to the usual massive reciprocating machinery is easily explained, particularly in view of the trouble formerly experienced with blades, etc. By the improvement of design and selection of proper materials, it may be safely stated that turbines can be obtained that will be as reliable and give as satisfactory results as any form of prime mover. (Applause.)

THE USE OF STEAM TURBINES FOR VARIOUS PURPOSES

LEIF LEE, Chief Engineer, and
KARL NIBECKER, Steam Engineer
Youngstown Sheet and Tube Company, Youngstown, Ohio

We have read with considerable interest Mr. Cutler's instructive paper concerning the various uses of turbines. In the main, we quite agree with his conclusions and the results of tests as shown by him.

While a wonderful saving of fuel has been shown by the use of exhaust steam from engines in the plant of the Tennessee Coal, Iron and Railroad Company, such a saving cannot ordinarily be shown by turbines as compared with the modern compound condensing engines. We beg leave to present some of our experiences with machines in service similar to that described by Mr. Cutler.

At The Youngstown Sheet and Tube Company's plant we have, during the last eight years, installed some 34 turbines under various conditions and service. Among our installations, we have one turbo blower operating on a blast furnace and one operating on Bessemer converters, as well as one mixed pressure turbine taking steam through regenerators from a 54″ x 66″ simple reversing engine. Our experience with these three installations might be of interest to the members of the institute.

TURBO BLOWER.

The turbo blower on our blast furnace and also the one on our Bessemer converters were put in operation about a year ago and, with the exception of a few short shut-downs due to minor mechanical defects, they have been in service since that time.

From extensive tests which we have run upon these machines, we are of the opinion that the two governing factors as to the advisability of the use of machines of this type in

preference to reciprocating engines are steam consumption and the working of the apparatus in which the air is used.

STEAM ECONOMY.

We have found that the steam consumption of the turbo blower, when operating with 150 lbs. dry saturated steam and 26″ vacuum, is approximately 10 per cent. in excess of the steam consumption of the engine per unit of air delivered. If, however, it is possible to obtain a 28″ vacuum for the turbine, this vacuum can be used to better advantage in the turbine than is possible in the engine. Under this condition the two steam consumptions become approximately equal or slightly in favor of the turbine.

It is thus seen that where an abundant supply of cold condensing water is not available, the blowing engine is slightly more economical in steam consumption than the turbo blower.

In view of the increased saving in first cost and fixed charges, as well as the saving in repairs, the turbine at present appears to be a cheaper method for handling air than a reciprocating engine even on vacuums as low as 26″. Below this point, the question becomes a rather doubtful one.

EFFECT OF WORKING OF FURNACE.

One of the strongest arguments advanced for the turbo blower has been the advantage of a steady blast. We feel, however, that it is at present a question whether this is in reality an advantage. It is a well known fact that the stock in a blast furnace must settle, yet it is an open question whether the innumerable small impacts of the blowing engine does not cause a more uniform settlement than the less frequent and larger settlements caused in the operation of the turbo blower. These conditions may not be serious for foreign or southern furnaces using coarser ores. The effect on furnaces using the finer Mesaba stock may mean an increase in flue dust from a furnace blown by a turbo blower amounting to enough to prohibit their use with these ores. We have found that the blower produces an excess of flue

dust over that produced by the engine when the furnace is working on the same burden and at the same rate of driving.

We have found a reduction in yield of as much as 5 per cent. which we have been able to attribute only to the different method of producing the blast. These values have been obtained by observations extending over a considerable length of time; and, therefore, we feel that this question demands more thorough investigation before giving the turbo blower an unqualified endorsement. This condition may, after all, be the determining factor in the selection of a blowing unit.

From careful measurements made upon the delivery from the blower, it appears that there is less variation in the amount of air delivered by the turbine than by the engine under varying conditions of atmospheric temperature and pressure when the engine is operating at constant speed and blower is operated at constant setting of the volume regulator.

The absence of vibration of the air lines is a marked characteristic of the turbo blower which will tend to a reduction in cost of maintenance of equipment.

TURBO BLOWER ON BESSEMER CONVERTERS.

While there may be a question as to the advantage of a steady blast in blast furnace operation, there appears to be no question as to its advantage on a Bessemer converter. A further advantage of the turbine for this service is its ability to maintain a uniform pressure under widely different conditions of delivery.

The blower as installed in our Bessemer Department is arranged to blow either one or two converters, or both, in parallel as desired. The curve shown will clearly demonstrate the much more uniform pressure maintained by the blower than by the reciprocating engine.

It will be noticed in changing from single to double heat that the variation in pressure and also the time which is required for the pressure to be restored to normal is very much less in the case of a turbo blower than with the engine. It is necessary for the operator to manipulate the throttle

valve of the engine in order to maintain the delivery pressure under these conditions, while in the case of the turbo blower the governor is entirely automatic, being controlled by the blast acting on the throttle valve.

Due to this characteristic, there is at all times available a more uniform blast pressure and thus better working conditions are produced. While we are not yet able to establish the fact, we are inclined to believe that due to this better regulation a reduction in the time of blowing heats and a consequent increase in tonnage can be obtained.

The steam consumption in this plant has been found to be governed by the same conditions as those mentioned for the blast furnace blower, i. e., the vacuum becomes the determining factor.

On the converter the service of the blower is much more severe than on the blast furnace and a considerably more rugged machine should be specified for this service.

SIMPLE REVERSING ENGINE WITH MIXED PRESSURE TURBINE COMPARED TO COMPOUND CONDENSING REVERSING ENGINE.

During the past four years we have been operating a mixed pressure turbine utilizing exhaust steam from our No. 1 blooming mill engine through regenerators.

About a year ago our No. 2 blooming mill, driven by a twin-tandem compound condensing reversing engine, was put in operation on practically the same service as our No. 1 mill. Both mills have a maximum capacity of 63,000 tons per month.

In multiple with regenerators on No. 1 mill, we have installed a large accumulator feed water heater, the arrangement of piping being such that the heater is given preference as to the use of the exhaust steam, this being admittedly the most economical means for the utilization of the heat. The water control to this heater is such that the water is admitted during the time when steam is available. The water thus heated is then stored in a large accumulating space.

We have made quite extensive tests on the two mills and

find that the steam consumption of the condensing engine is practically one-half that of the non-condensing engine.

It has been claimed by some engineers that it is impossible to maintain a high degree of vacuum in the low-pressure cylinder of a reversing engine. We have, however, disproved this fact in the case of our No. 2 mill, indicator cards which, as well as recording vacuum charts, we beg leave to show you.

It will be noted that the vacuum in the low pressure cylinder is 22″ and at no time are we troubled by a reduction in vacuum when making reversals.

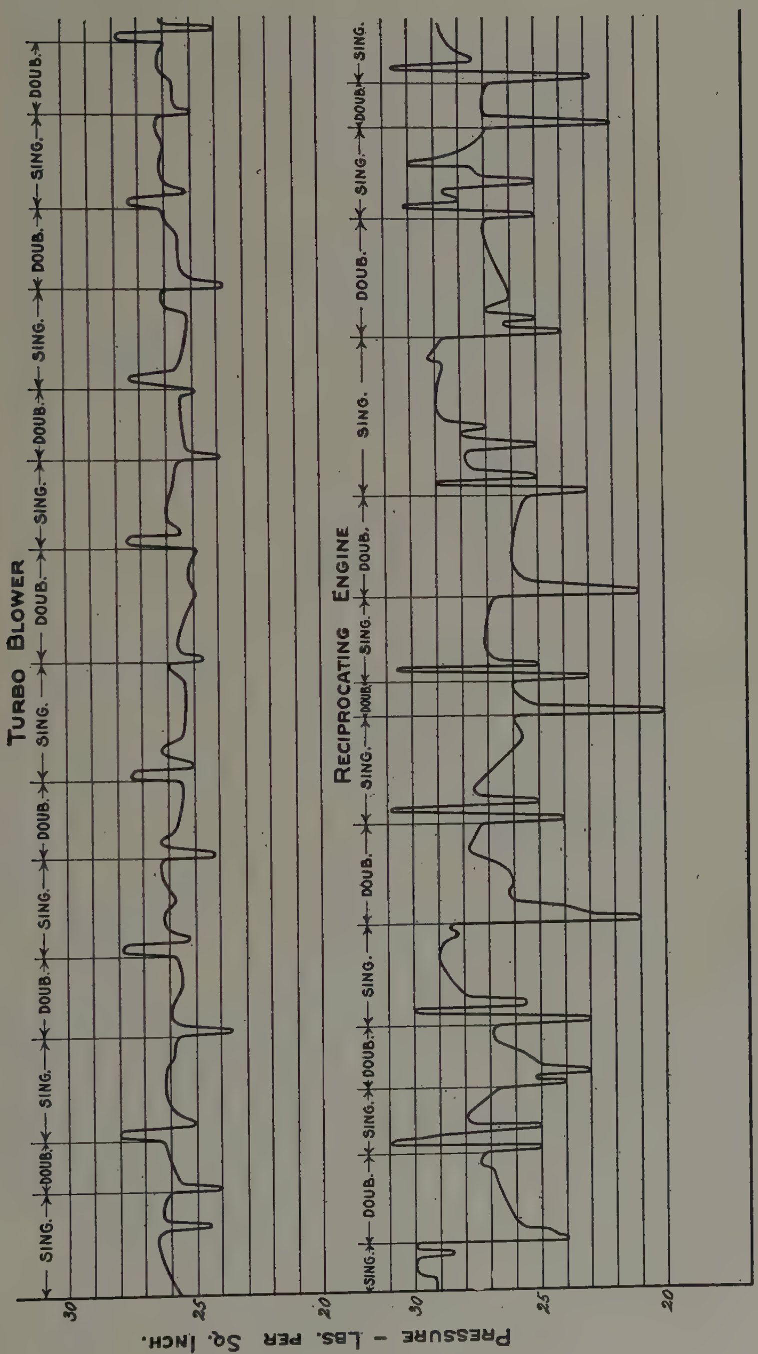
From the above facts, it will be seen that if a mixed pressure turbine can be installed, producing power equal to that of the reversing engine, the scheme becomes a good one. Our experience, however, has been that it would require steam regenerators of enormous capacity in order to handle the steam fluctuations properly; also that the regenerators must be of very heavy construction in order to withstand the impacts of the large quantities of exhaust steam intermittently admitted. High pressure steam, we find, must be used frequently when low pressure steam is not available. It, therefore, becomes exceedingly important to install a mixed pressure turbine having an exceptionally good high pressure steam economy, as well as low pressure, in order to make the installation a paying proposition.

In the case of the feed water heater, however, the same is used to the best possible advantage, as the water supply to the heater is controlled in synchronism with the steam supply.

We feel that probably the only justification for the installation of regenerators and a mixed pressure turbine is in a case such as ours, where the mill cannot be spared for a sufficient length of time to replace the existing engine with a compound condensing engine.

In the case mentioned by Mr. Cutler, they have several engines exhausting into one regenerator system, thus reducing the fluctuations in steam flow and greatly simplifying the problem of regeneration.

The average steam cost for our No. 1 Mill is $10,000 per month. In this is included the high pressure steam for


Turbo Blower
Reciprocating Engine
Pressure – Lbs. per Sq. Inch.
30
25
20
30
25
20
SING.
DOUB.

operating the mixed pressure turbine when running on high pressure. It is figured that the value of exhaust steam, used for heating feed water, approximates $3,000.

The value of the electricity generated by the mixed pressure turbines is $2,500 per month, leaving a net steam cost per month to the mill of $4,500.

The total average steam cost of our No. 2 blooming mill is $3,000 a month, which shows a saving of $1,500 a month in favor of the compound condensing engine.

From a comparison on our No. 1 and No. 2 mill engines, we believe that the proper installation is a condensing reversing engine, the feed water heat being obtained from boilers, fan and stoker engines and all other auxiliary machinery.

In case this is not feasible, the next best scheme is the combining of regenerators and feed water heater in connection with the mixed pressure turbine with the best possible high pressure steam economy.

While we fully realize the obligations the iron and steel manufacturers owe to the pioneers in the manufacture of turbines for mill service, still we feel that they should not assume their adaptability to every condition of service. Their entry into the field has spurred the engine builders to new efforts as exhibited by the high speed blowing engine and the Uniflow type of steam engine.

The steel mill engineer, we feel should use a considerable amount of caution in the selection of the prime mover best adapted to his local conditions and should not be led astray by the alluring claims of the turbine builders.

We feel that with the data which is becoming available through the agencies of such organizations as this Institute, the engineer in the future will have available such information as will enable him to make the proper selection of prime movers and we cannot too highly recommend the publication and dissemination of the results of tests and investigations and further data tending to this end. (Applause.)

THE USE OF TURBINES FOR VARIOUS PURPOSES

ALEXANDER L. HOERR

Steam and Hydraulic Engineer, National Tube Company, McKeesport, Pa.

It was the writer's privilege to visit the Ensley plant of the Tennessee Coal, Iron and Railroad Company in April, 1910, at which time the non-condensing condition mentioned by Mr. Cutler still existed. The plant at that time contained about thirty large engines for blast furnace, mill and power house service, three large pumps for general service and a number of auxiliary engines and pumps. All of the units mentioned were operated non-condensing except one of the large pumps. This equipment was supplied with steam by boilers having an aggregate rating of about 31,700 B.H.P. The electric generating capacity was 3,800 K.W., of which only a little over half was regularly used. This clearly illustrates the very limited application of electric power. Work was being done in several departments to remedy these conditions and Mr. Cutler's paper clearly shows the very excellent results obtained.

Following a description of the low pressure turbine and cooling tower installations and of the accompanying extension of electric power supply lines, the statement is made in the paper that "this has been accompanied by an increase in product and a reduction in coal consumption . . . estimated to be at the rate of 200,000 tons of coal per annum." This is a most remarkable saving and very creditable to those responsible for it. The writer, however, questions the completeness of the statement of the causes of this saving and questions the possibility of such a saving through the installation of low pressure turbines alone.

SOME SAVING DUE TO COLLATERAL IMPROVEMENTS.

To secure more power from the same fuel through the use of low pressure turbines is entirely possible, but to secure so much more power from so much less fuel does not

seem possible. The saving must be to some extent due to collateral fuel improvements, such as the connecting of boiler houses by steam mains, the substitution of coke oven gas for coal, improvement in the pumping situation, substitution of motors or turbines for small inefficient engines or similar changes.

The writer does not wish to minimize the value of the low pressure turbine as applied to non-condensing engine equipment, but rather to avoid claiming too much and causing disappointment and prejudice against the turbine when it fails to meet the claims made. A more complete description of the other plant improvements made and an estimate of the coal saved by each would be of great value.

The fuel consumption of a non-condensing mill engine is generally increased by the application of a low pressure turbine because the back pressure is increased. If the engine can carry its maximum load at normal steam pressures with this increased back pressure, no loss to the plant results, providing the load on the low pressure turbine can be so adjusted as to avoid blowing any considerable quantity of exhaust steam to the air. This has been accomplished in the plant under discussion by the use of regenerators at No. 2 Power House to absorb the irregularities in steam supply and by operating in parallel with No. 1 Power House so that the load on each turbine can be adjusted to the steam available.

The combination of engines and turbines in the two power houses is almost ideal, only two of the engines being reversing while four are connected to electric generators, giving on the whole a much more regular supply of steam and better opportunity for adjusting the turbine load than is usually obtained. The pressure curves from the low pressure steam system are the best evidence of satisfactory action, the sections given in the paper showing that the regenerator pressure at no time reaches the point at which the relief valve opens.

The series of tests made on the blast furnace engines and on the low pressure turbo-blowers connected to them are very complete and very enlightening.

The most interesting thing they show is that a furnace can be satisfactorily blown by a rotary blower. Many blast furnace men have questioned the ability of the blower to supply a constant quantity of wind against varying pressures, but since the author states that "there has been no substantial difference in the operation of a blast furnace by blowers as compared with engines," we must assume that the regulation is such as to fully meet this requirement. It should also be noted that the statement quoted above tends to disapprove the claim made for such blowers, that better operation would result due to more regular blast. It, however, confirms the frequently expressed opinion of blast furnace men that irregularities in ore, stone, etc., have more influence than irregularities in the blast.

Application of Turbines to Iron and Steel Mills.

The general subject of gas versus turbo-blowers, which was discussed at the May Meeting in 1913 by Messrs. Freyn, West and Rice, is not involved at this plant. There can be no question as to the economy resulting at this plant from the utilization of existing boilers and engines with a low pressure turbo-blower, for the reason that the engines and boilers were in good condition and would be serviceable for a good many years.

The general subject of steam turbines in iron and steel mills is one of great and growing interest. As stated by the author of the paper under discussion, ten years ago it was a rare thing to find a steam turbine in an iron or steel mill, while to-day nearly all of the important mills have one or more turbines in use. They range in size from that of the turbine driving a 35 K.W. exciter set to that of the turbine driving a 3000 K.W. alternator. In some few cases this latter size has been exceeded. In discussing Mr. Hodgkinson's paper on "Recent Progress in the Building of Large Steam Turbines," read at the May Meeting of the Institute in 1914, Mr. Stott speaks of "small sized" turbines of about 5,000 K.W. rating. On the basis of this classification practically all of the turbines in which the steel mill manager or engineer will be interested will be "small." Few plants

have such power requirements as to call for generation in 5,000 K.W. units.

The principal use for turbines in steel mills has been for driving electrical machinery, but in addition to various uses in this connection they have been used with success in many mills for all sorts of pumping service including boiler feed, condenser, hydraulic, and general low pressure, service. Also for blowers other than those on blast furnace work, such as for forced draft on boilers. In one case at least in this country a turbine has been applied direct to a rolling mill, but as the plant has been in operation only a short time, and no data have been given out regarding its operation, it is not possible to say with what degree of success this has been done.

In considering the application of turbines to any service in a plant, one should not jump to the conclusion that because their application to a plant such as that at Ensley has been economically sound and successful, that therefore it will be universally so.

The Problems Involved.

In the case of the low pressure turbine applied to a mill engine two different problems may be presented: First, the case of an existing mill with simple non-condensing engines and boilers in use, turbines and condenser to be purchased; second, the case of a proposed new mill, with boilers, engines, turbine and condenser, all to be purchased.

In the first problem, if the engine is of such type and in such condition as to indicate a considerable life for it, and if it is large enough to carry its load with some increase in back pressure, then a low pressure turbine and condenser will probably effect a greater saving than any other improvement that could be made, even though some steam is lost through the relief valve. This is true because the use of the existing equipment reduces the investment required and therefore the charges against the plant.

In the second problem, conditions are very different, and in many cases will require the installation of different equipment to secure the maximum economy. In this case, if the

proposed mill will furnish a reasonably steady load for the engine so that the supply of exhaust steam is regular, then the same solution may hold as for the first problem.

If, however, the more usual condition will prevail and the mill load will fluctuate rapidly through a wide range, sending the steam to the exhaust system in violent puffs, the same solution will not do. The turbo-generator in most cases will carry a load originating largely outside the mill which furnishes the steam. The changes in this load will not synchronize with the changes in the exhaust steam supply and although some peaks will be flattened out by the regenerators, there will be frequent loss of steam to the air.

This will be a complete loss to the system and will prevent a realization of the calculated economies.

In such cases as these it is the writer's belief that the installation of a compound reversing condensing engine for the mill drive is best. This will carry the mill load with the minimum amount of steam and the amount saved over non-condensing conditions can be supplied to a high pressure turbine for the generation of the necessary power.

Thermal Efficiency Not the Only Determining Factor.

In these problems the solutions adopted do not necessarily favor the combination having the highest thermal efficiency but the one producing the best plant economy.

The point to be made is that after all it is not the combination having the highest heat efficiency that we want, but the one having the highest dollar efficiency. It is immaterial to the man who furnishes the money whether it be spent for coal; for material in repairs, such as iron, steel or brass; for oil; for labor; or for interest on investment. What he wants is the performance of a certain plant function for the minimum total expenditure, calculated for the probable life of the machinery performing this function.

The first turbine units with which the writer had any experience were installed in a steel plant in 1905. They were used for driving centrifugal pumps which were con-

nected to the general mill supply lines. They were purchased after an investigation of numerous turbine installations in New York and Eastern Pennsylvania, all of which gave the impression that the turbine was a very reliable power unit. This purchase was not based on the thermal efficiency of the units alone but on the combination of the cost per unit, the cost of building and foundations and the cost of steam as determined by the efficiency of the unit and the price of coal at the plant. Compound condensing reciprocating pumps would have reduced the cost of the steam, but would have so greatly increased all other items of cost as to make their installation a losing proposition. In this, as in many other cases, the use of the less efficient unit resulted in the higher plant economy.

It is interesting to note that the three pumps installed in 1905 have been followed by eight others pumping against total heads ranging from 20 feet to 1,400 feet, and that all are reported to be operating satisfactorily both from the mechanical and investment standpoint.

Turbine-driven centrifugal pumps in the large sizes, operating under steam conditions such as obtain at steel mills, that is, saturated steam at not to exceed 165 pounds pressure, can be purchased with a guaranteed duty of approximately 120,000,000 foot pounds per 1,000 pounds of dry steam. With better steam conditions this can be increased. With such units available no plant with coal at $2.00 or less a ton can afford to install compound reciprocating pumps for general service without making a careful comparison of the total operating costs of both types.

Resulting Changes in Machinery Driven.

The adoption of the steam turbine as prime mover makes necessary a change in the machinery driven. The air tub gives way to the rotary blower, the plunger pump gives way to the centrifugal pump, and the large slow speed direct-current generator gives way to the compact high speed alternator. In the application to direct mill drive no change would ordinarily be made, but even here some few

cases would permit the use of smaller diameter rolls at higher rotative speeds.

A great many turbine applications must be made through one or more gear reductions since the economical turbine speed is frequently above that of the driven machine. These gears have been a stumbling block in the path of the turbine in very many cases, the operating men questioning their reliability under mill conditions. These doubts have been quite generally dispelled by the successful operation of many installations in recent years. Satisfactory high speed gears are now made in all reasonable ratios and in all sizes, from that required for a boiler feed pump drive to that required for a mill drive.

Since any desired gear ratio can be obtained, the speeds of the turbine and of the driven machine can be independently determined so that each may operate to the best advantage.

In the case of pumps handling dirty water, and this would include nearly all steel mill units, it is advisable to set the speed below that required for the maximum efficiency because of the operating difficulties which may be encountered. The higher speed for a given capacity causes a reduction in the size of all of the passages through the pump and renders them liable to be clogged by pieces of wood, etc., which may pass the screens. This will tend to unbalance the pump and cause an end thrust on the gears which was not anticipated in the design. The high velocity of the gritty water through the impeller will also result in rapid deterioration and loss of efficiency.

The National Tube Company has low pressure turbine-driven generators at three of its plants—National, Lorain and Kewanee—and is installing high pressure turbine-driven service pumps and boiler draft blowers at National Works.

A complete description of the National Works low pressure turbine and regenerator installation with test data is given in a paper written by Mr. F. E. Leahy, and published in the Proceedings of The Engineers' Society of Western Pennsylvania for February, 1914, so it will not be necessary to duplicate it here.

Since the reading of this paper, however, there has been an addition to the plant, a description of which may be interesting.

Prevention of Field Grounds.

The turbine station is located in a particularly dirty place, in the immediate vicinity of a blooming mill, slabbing mill, pig casting machine, and ladle house, and on account of metallic dust in the air used for cooling the turbo generator, considerable trouble was experienced due to the insulation on the field winding breaking down and causing grounds.

This happened on three different occasions, each time requiring about five days' time to remove the field, repair the insulation, and put the field back in place. To overcome this trouble, an air washer, or as it is termed by the manufacturer, a humidifier, was installed for the purpose of cleaning the air used for cooling the generator. This apparatus is guaranteed to remove 95 per cent. of all the solid matter entering it, and it is also guaranteed that no particles of water that will be injurious to the generator will pass through the humidifier. In the process of cleaning the air the apparatus will saturate it, obtaining thereby the greatest possible cooling effect and increasing the capacity of the generator by about 15 per cent. for the same maximum temperature of the windings. The humidifier has a normal capacity of 16,000 cu. ft. of air per minute with an overload capacity of 20,000 cu. ft. per minute and requires about 80 gallons of water per minute.

This apparatus was put in operation June 10, 1914. The sediment found in the settling tank on July 8, 1914, filled 10 buckets of about 540 cu. in. capacity each; on September 6, 1914, 17 more buckets of sediment were removed from the settling tank. While some of this dirt came in with the water, the bulk of it was taken from the air passing through the cleaning apparatus.

In the operation of the humidifier, the air is drawn through a chamber filled with a mist-like spray that is thrown by a number of nozzles against the current of in-

coming air. In passing through this mist the heavier foreign particles in the air become wet and heavy and fall to the settling tank. To remove the lighter particles there is a second set of nozzles which throw a spray at right angles to the flow of air and in the direction of the settling tank. This removes dust or soot that would otherwise pass through the humidifier with the air. After the air passes through the spray chamber it is passed through a system of baffle plates which removes all moisture that would be injurious to the generator.

While it is too soon to say positively that this installation will entirely prevent field grounds, there is every reason to believe that it will reduce the chances of such accidents to a minimum.

To summarize the case of the turbine for mill use the writer would say that with the steam engine and gas engine it has a place as an economical prime mover. It is not the best prime mover for all purposes and the question of its use will often be decided by local operating conditions. Its adoption should never be based on a calculation which overemphasizes thermal efficiency, since thermal efficiency is only one of many factors, the sum of which is a measure of plant economy and the object sought is the maximum value of this sum. (Applause.)

Here, on motion duly made, seconded and carried, a paper prepared by Mr. Richard H. Rice, General Electric Company, Lynn, Mass., discussing Mr. Cutler's paper, was authorized to be included in the proceedings, the author not being present to read it.

USE OF TURBINES FOR VARIOUS PURPOSES

Richard H. Rice

Engineer, General Electric Company, West Lynn, Mass.

Mr. Cutler's paper sets forth in a very interesting manner the result of actual experience with three turbo blowers covering a period of about two years, and operating under rather different conditions than are usually met with in connection with blowing of Northern furnaces. This on account of the character of the ores and cokes used, resulting in more frequent checking and less regularity of working conditions.

More frequent checking of the furnace disturbs the blast conditions and prevents the realization of any substantial benefit from the more steady blast of the turbo blower. Nevertheless, Mr. Cutler's table (page 307) shows a reduction in the coke ratio of about two per cent. This table shows a difference in blast pressure in the case of engines and blowers which is entirely accidental, as shown by much more complete records covering a very much longer period.

Mr. Cutler describes in detail the very accurate tests which he made on the delivery of the blower as compared with the original graduations of the air governor which resulted in recalibration of this governor. It has been found that in certain cases, due to variations in the conduit shapes through which the air is brought to the air governor, there is likely to be a difference between the calibration made in the shop and that made in the field. Therefore, at nearly all the installations of such apparatus which have been made by the General Electric Company, the air governor has been calibrated in place. Mr. Cutler's work also brings out clearly the considerable difference between the displacement air measured off by an engine and the actual air as measured by calibrated means, which are extremely accurate in case of steady blast of a turbo blower.

Difficulties of Measuring Results.

Mr. Cutler, evidently with full realization of the difficulties of measuring air which is under variations of pressure (as

is that from a reciprocating air tube), takes as a basis for calculations of volumetric efficiency the ratio between displacement of engines and indications of turbo governors for two alternate periods of blowing; and this method is probably fully as exact as the method, used as alternative by him, of throttling the air supply from an engine and measuring the air by a nozzle. I have found it impossible with reciprocating engines to secure a sufficiently steady flow in this manner to enable exact measurement to be made. The general result of both these methods would be in error in a direction favorable to the reciprocating engines. Therefore, Mr. Cutler's comparisons may be accepted as conservative. Mr. Cutler's work in connection with turbo blower air measurements has been very exact and he has, as described in the paper, used double means of measurement with calibrated nozzle both in the suction and in the discharge.

It is shown by the results reported by Mr. Cutler that the installation of low-pressure turbo blowers in connection with high-pressure blowing engines makes possible economies of the same order of magnitude as is shown by the installation of low-pressure turbo generators in connection with high-pressure engine driven generators in electric power stations.

Experience at Ensley.

The arrangement at Ensley where existing engines have been coupled up to low-pressure blowers has therefore been shown, by this experience, to be absolutely practical, and to result in a very large increase of blast for the same amount of steam used. The operation of the apparatus is satisfactory, and Mr. Cutler states (page 315) that the costs of operation are materially less with turbo blowers than with engines, a result which is entirely reasonable and to be expected, duplicating the experience of users of turbo generators throughout the country.

Experience at Youngstown.

Messrs. Lee and Nibecker find an excess of steam consumption in case of a high-pressure condensing turbine as

compared with a reciprocating blowing engine of ten per cent. when using 150 lbs. dry saturated steam and 26″ vacuum. The accuracy of this figure depends on the important question whether the quantity of air delivered by the two types of apparatus is the same, as well as the design and efficiency of the particular turbine used as driver.

The paper of these authors contains data which tends strongly to show that the turbo blower in this case is delivering considerably more air than the engine.

With the same delivery of actual air and a turbine of proper design the turbo blower should use less steam than the engine under the conditions stated.

Conclusion.

In furnaces operated in the North where checking is infrequent it is the custom to operate the turbo blower with constant setting of the air governor, and in this way extremely uniform results are obtained from the furnace. This method of operation does not seem to be possible in connection with Southern irons on account of the peculiarities of the ore and of the fuel. It must be emphasized, however, that the turbo blower is an apparatus which has different characteristics than its alternative, the reciprocating apparatus, and it is necessary, therefore, to study the characteristics of the apparatus and utilize them to the best advantage in order to secure the best results from the combination of blower and furnace. It is most frequently the case that operators of blast furnaces supplied with this type of apparatus overblow the furnace, and this leads to difficulties such as those met with at the Youngstown Sheet & Tube Company, where there seems to be no question that too much air is being supplied at times when the turbo blower is being operated. I believe that at the Tennessee Coal, Iron & Railroad Company the same experience has been had. It cannot be too strongly emphasized that the unit of volume in a turbo blower is entirely different from the unit of volume in a reciprocating engine, and the first thing that it is necessary to do in putting apparatus of this type on the furnace is to determine the correct volume of air.

THE USE OF TURBINES FOR VARIOUS PURPOSES

Frank G. Cutler

Chief, Bureau of Steam Engineering, Tennessee Coal, Iron and Railroad Company, Ensley, Ala.

In reply to Mr. Hoerr's suggestion that a detailed description of other plant improvements be made, with an estimate of the coal saved by each, I would say that it would be impossible within the limit of this paper to detail all the factors that would affect a comparison of this nature in a way that would be of value to one not familiar with the local conditions, and for this reason I do not believe it necessary to go into details. Also I do not consider 200,000 tons the limit of the possible saving by the low pressure turbine installation.

For example: Before the installation of our low pressure turbo generators at our No. 2 Power House, high pressure steam for power purposes was taken from our blast furnace boilers, which also supplied the blooming mill with part of their surplus steam. As the electrical power demand of the mills was considerably higher when they were in operation, the demand for steam for power purposes was greater at the same time that the maximum of steam was required for rolling purposes, making it necessary to have an excessive number of boilers in service at the mill for the average load, as a result of which condition these boilers were not operated economically.

After No. 2 Power House was put into service, the live steam required for power purposes was at a minimum during the period of maximum rate of rolling, so that in 1913, with a 30 per cent increase in product at the mill and an electrical output at No. 2 Power House more than twice as high as No. 1 Power House in 1910, there was an average of 25 per cent less horsepower of boilers in service at the mill. The total steam delivered to the blooming mill system per ton of blooms rolled (which in both years included steam delivered from the furnaces and generated at the mill boilers and safety

valve loss at the mill) was practically the same for both years, so that the improvement of efficiency at the blooming mill system, due largely to more efficient boiler conditions, compensated for the increase in steam consumption of the mill engines, due to their working against slightly higher back pressure, as well as the high pressure steam used at No. 2 Power House.

By utilizing the exhaust of the non-condensing reciprocating engines at No. 1 Power House in the low pressure turbine, the power output per unit of steam supplied is practically doubled, so that had the power demand required the operation of No. 1 Power Station reciprocating engines in 1913 at the same rate as during 1910, the total power from exhaust steam and from live steam supplied to power at the two stations, without increasing the steam delivered to the mill system per ton of steel rolled, would be the rate over 40,000,000 kw. per year; and to generate this power from coal under former conditions would have required the burning of over 100,000 tons of coal per annum. It should also be noted that the power demand in 1913 was not sufficient to utilize all available exhaust steam from the mill engines and that this load is only about 50 per cent of the rated capacity of three of the four low pressure turbines.

Savings Effected.

In my paper it was shown that the original blowing engines operating non-condensing required 48,180 pounds of steam per blast unit, while by operating three furnaces by turbo blowers from the exhaust of engines on other furnaces the steam per blast unit was reduced to 25,000 pounds, a saving of 23,180 pounds per blast unit. With the 1913 average of 8,540 blast units per month for six blast furnaces and an evaporation of 7 pounds steam per pound of coal, this would mean a possible saving of 150,000 tons of coal or gas equivalent.

Not all of the saving has been realized, as there have not been six furnaces in blast since the completion of the turbo blower installation, and the power conditions in the past have not been such that the full operation was required.

The figure of 200,000 tons includes the saving at the mines and the saving by the shutting down of boiler plants at the shops and local pumping station, because power or steam for their operation is now obtained from the main boiler and power plants. It includes the saving due to better boiler conditions, incident to the supply of better water to the treating plant, which is included in the reduction of coal consumption at the main boiler plants. It also includes an estimate of the coal that would have had to be burned to supply steam to non-condensing reciprocating engines to generate the additional power supplied to the several plants.

The increase in gas credit due to use of by-product gas on the boilers over the saving in fuel formerly obtained from waste heat from bee-hive ovens has been allowed for in this estimate.

Local Conditions Often Determine Choice.

It was not my intention to convey the impression that an installation of low pressure turbine is necessarily the most economical installation for every case, but that for our conditions it was in our opinion the logical installation.

The information given by Messrs. Lee and Niebecker about comparative steam consumption of their two Blooming Mill engines is a further confirmation of this point, although there seems to be some loss at their No. 1 Mill. Taking \$2,500 from \$10,000 leaves \$7,500 as the cost of steam furnished their No. 1 Mill, as compared with \$3,000 to the No. 2 Mill disregarding the value of \$3,000.00 assigned to exhaust steam supplied to the feed water heater. As the statement is made that the steam consumption of the condensing engine is practically half that of the non-condensing engine, there is evidently a loss, probably of exhaust steam, delivered at a rate in excess of the capacity of the heater and regenerator or of being utilized by the low pressure turbine.

With reference to Messrs. Lee and Niebecker's statement that there was a reduction of 5 per cent in yield when their furnace was blown by the turbo blower, I would say that a comparison of our furnace operating records does not show any greater loss of flue dirt or lower yield when the furnaces

are blown by turbo blowers, and it is my opinion that there must be some local condition or method of operation at their plant which is the cause of the difference they have noted. The instantaneous fluctuation in blast pressure at the furnace when blown by engines at our plant has been found to be so small (about one tenth of a pound per square inch) that its effect upon the rate of settling can hardly be measured.

I fully agree with Mr. Hoerr that the decision as to the installation of the turbine is often determined by local operating conditions and that the adoption of the form of prime mover is to be governed by many factors, of which thermal efficiency is only one.

THE REPAIR DEPARTMENT OF A MODERN STEEL PLANT

John Hulst

Chief Mechanical Engineer, Carnegie Steel Company, Pittsburgh, Pa.

The steel plant has no parallel both in the continuity of its processes and in the very large units of which it is composed, and which have been made necessary from the standpoint of economy in operation.

From the reduction of the ore in the blast furnaces through the processes of steel making and rolling, the one process is closely linked with the next, so that practically it is continuous.

The steel plant of to-day with its blast furnaces, each having a capacity of 500 tons or more, with its steel producing units still increasing in size, and with its rolling mills of very large capacities—and these units all dependent upon one another—presents difficulties seldom encountered elsewhere.

The vast amount of capital invested as a total, as well as in each of the large separable units, makes it of prime importance that all operations, from the ore to the finished steel, be interrupted to the least possible extent.

The success of a steel plant of modern design is therefore largely dependent upon the extent to which delays are eliminated, and this constitutes the daily study of the mechanical and electrical superintendents and their forces. Their success in turn is dependent, not only on their keeping in close touch with the condition of all machinery from day to day, knowing when replacements due to wear will have to be made, anticipating even the breaking of a weak part, but also to a large extent on the resources the repair departments have at their disposal.

An intimate association with the different classes of machinery will soon make manifest the more frequent breaking or necessary replacing of one part as against

another, and it is from this actual experience that one is enabled to determine the number as well as the kinds of spares it will be necessary to carry.

Steel plant practice in order to meet the extremely hard and continuous service has made use of all resources available; we might mention the use of very low strains, the more liberal use of steel castings, the use of rolled steel wherever possible for gears, wheels, etc., and the elimination of cast iron except where stability is required or severe strains are absent or where subjected to abnormal heat.

However, wear cannot be avoided and continues until replacement is necessary or breakage occurs, also accidents due to the unexpected, as explosions, cold steel in rolling, etc., and those due to mistakes in judgment, all leave their share of broken parts to be replaced.

In addition to these we have the replacements made necessary through constant exposure to excessive heat, such as ingot molds, stools, furnace doors, valves, etc.

The repair facilities, therefore, loom up as the mainstay of continuous operation so necessary for the final success of the plant.

The Repair Department.

The preparation of spare or repair parts may be divided into two distinct operations and classes of facilities:

A—The Making of the Rough Materials:

1—Iron Foundry,
2—Steel Foundry,
3—Roll Foundry,
4—Brass Foundry, etc.,
5—Pattern Shop and Pattern Storage Building.

B—The Finishing of the Rough Materials:

1—Machine Shop,
2—Electric Repair Shop,
3—Forge Shop,
4—Pipe Shop,
5—Structural or Boiler Shop,
6—Roll Shop,
7—Locomotive Repair Shop.

(A)—The Making of the Rough Materials.

This classification leads us to the consideration of foundries for iron, steel, brass, etc. Other rough materials, such as structural shapes, plates, forge steel, etc., can readily be eliminated from our consideration, as they are products of steel plants and each plant would furnish all of this class of rolled material that comes within its schedule. The question as to what extent these facilities should be included in steel plant equipment is purely an economical one.

We have in mind a moderate size steel plant completely equipped for the successive processes from the ore to the finished billets, tin bars and rails, having a capacity of 90,000 to 100,000 tons of rolled steel per month, which used the following tonnages of repair castings during the year 1913:

	Tons	Number of Pieces
Iron Castings	1,398	23,377
Steel Castings	1,058	6,937
Rolls—Steel	722	206
Rolls—Iron	606	216
Brass Castings	18	13,400
Babbitt	64.5	

(A-1)—The Iron Foundry.

The iron castings used in repairs may be divided to advantage into two classes:

1—The simpler and easily molded castings.
2—The complicated castings.

1—There can be no doubt that a foundry having ample facilities for making the simpler iron castings would be advantageous both from practical and economical standpoints, especially when we have in mind the possible location of the foundry readily accessible to the blast furnaces, using the hot metal direct for all castings such as floor plates, wearing plates, mold stools, etc., in fact for any castings which do not have to stand severe working strains. This has been demonstrated at some plants in the making of all kinds of open sand castings at the end of the furnace cast house, making use of the hot metal direct from the

furnaces. Of course this practice is limited by the small amount of space available.

2—As to the complicated castings, requiring special molding facilities, complicated core work, etc., on account of their infrequent occurrence, there would be a question as to the advisability of making these, and the solution can only be found in local conditions. The answer is dependent upon:

First—The number of these castings, and their resultant tonnage.

Second—The proportion of skilled versus unskilled labor required.

In general, it would not be an economical proposition for a moderate size steel plant to be equipped for taking care of special high-class foundry work, because a single plant would not have sufficient work of this kind to keep their expert men busy and skilled labor would be working on the rough class of work.

(A-2 and 3)—The Steel and Roll Foundries.

The steel foundry, as also the roll foundry, as a plant facility can be fairly questioned as to economy when dependent upon a single plant for their tonnage and also on account of their special requirements both in labor and material. These foundries necessarily carry a considerable overhead expense and a lack of tonnage is fatal to their success.

The steel foundry based on acid or basic open-hearth furnaces requires almost continuous operation in order to keep the furnace repairs within reason. The available tonnage of steel castings based on figures previously given is about 1,058 tons annually, or an average of 3.5 tons per day. This would mean a one-furnace foundry running about one heat per week, a serious condition for open-hearth practice, and one not to be considered except in direct connection with open-hearth steel plants, so that part of the open-hearth product can be readily diverted to the foundry, thereby saving the cost of re-melting and making

it possible to obtain the advantages due to continuous operation of open-hearth furnaces. Interrupted open-hearth service is detrimental, either from the alternate cooling and heating up of the furnaces, or the continuous heating required between casts with large idle periods becomes serious from an economical standpoint.

(A-4)—The Brass Foundry, Etc.

The brass foundry as well as the babbitt pot should be universal plant facilities for the following reasons:

First—The small amount of space required.

Second—The small investment necessary.

Third—The large number of brass castings, such as bushings, etc., required and available for the brass foundry and the numerous bearings, slides, boxes, etc., which require babbitting and are available as a source of revenue from the making of babbitt.

Fourth—The fact that these two materials, brass and babbitt, are largely used throughout all machinery to take the brunt of the wear and require frequent replacement.

Fifth—On account of the rough service, a cheaper grade of babbitt can be used successfully on most of the mill machinery.

(A-5)—The Pattern Shop and Pattern Storage Building.

The pattern shop and pattern storage building have always been classed as an important plant facility in connection with repairs:

First—On account of the necessity of patterns.

Second—On account of the repeated use that can be made of these patterns.

Third—The necessity of owning these patterns in order to make their repeated use available, as well as to facilitate procuring competitive prices on the castings.

Fourth—The fact that these patterns are destructible and should not be subjected to excessive handling or exposure to weather requires that they be properly housed.

(B)—The Finishing of the Rough Materials.

This covers the shop facilities with which every plant is equipped to a greater or less extent, and is based not only on its economical value but also on its practical necessity. Shop facilities are the rock bottom on which successful and continuous operation depend. To what extent they are desirable or economical may be broadly stated as follows:

A modern steel plant should have sufficient shop facilities to take care of all ordinary repairs by working day turn, thus taking advantage of the maximum amount of light possible. This then leaves a margin for exceptional repairs or even considerable work on the finishing of materials for construction purposes by working night turn.

In this way it is possible to get the best results during normal running of the plant, and we can still make use of the facilities to great advantage during construction or reconstruction periods. It is due to this that we find such extreme variations in shop equipments, the poorly equipped plant being forced to run their shops more or less double turn, at a sacrifice of economy and flexibility in capacity.

Shops.

In general, they should be centrally located, easily accessible, and should have good roadway and track connections with all parts of the plant. It is also very important that considerable space be allowed for future extension of these shops in order that they may keep up with the growth of the steel plant. For the proper storage of general supplies the shops should have a storeroom for classifying and keeping record of all supplies which, due to their size, would be lost, or, due to their deterioration, would be spoiled if stored in the open. There should also be a general yard for the storage of materials in the rough provided with proper handling facilities for the storing and handling of these materials. All such facilities tend to make this material more available as well as more easily accounted for, reducing loss or unnecessary duplication.

(B-1, 2 and 3)—The Machine, Electric Repair and Forge Shops.

The most important repair facility for the finishing of the rough materials is the machine shop, and closely allied with it are the electric repair and forge shops. The electric repair shop has a great deal of its work done in the machine shop and a large proportion of the product of the forge shop has to go to the machine shop for final finishing. The work of these three departments either overlap or the one does the preliminary work for the other. It would seem justifiable, therefore, to consider the advantages accruing by concentrating these shops so that ready communication and transfer of materials from one to the other may be had and the duplication of machinery for similar kinds of work may be avoided.

The final results obtained from the use of these repair facilities both as to amount of output and economy will largely depend upon:

First—That ample floor space has been provided for the final fitting, assembling and loading of materials.

Second—That proper handling facilities, cranes, track system, etc., are available.

Third—That the equipment has ample capacity.

Fourth—That the large machinery be placed so that materials may be handled to and from it by means of the crane.

Fifth—That ample working space be provided around machinery to make it accessible and safe.

Sixth—That a maximum amount of light as well as ventilation has been made available.

Shop Equipment.

(a)—The most important machine shop tool is the lathe, being capable of doing all kinds of work, such as boring, facing, drilling, threading, and with special attachments may be called our most universal and adaptable machine. The lathe equipment covers a very large field in repair work, which accounts for the variation in sizes

and lengths of bed required. Sizes range from 14″ to 60″, with lengths of bed from 6′ to 30′.

(b)—Equipment should have ample capacity, for instance:

Lathe beds should be of sufficient length to prevent the necessity of turning the piece end for end in order to complete the job.

The large planer should be provided with a removable housing on one side so that additional flexibility may be had as to the maximum width of piece that can be finished, and at the lowest first cost.

Planers should be equipped with side heads in order to eliminate as much resetting as possible.

(c)—Additional serviceable tools which are gradually becoming standard on account of their adaptability should be provided:

The horizontal boring mill capable of milling, slotting, boring, etc., is now recognized as a most useful tool.

The turret lathe for the duplication of parts is a very economical tool and flexible as to the kinds of work it can do.

The gear cutter or planer, due to the increased use of cut teeth in general mill gearing, is fast becoming a necessity.

(d)—Machine shop tools in general, such as planers, drill presses, shapers, slotters, bolt cutters, key seaters, and grinding machinery have been fairly well standardized and the choice between the different makes is largely a question of design as regards stability, accessibility and simplicity.

(e)—The forge shop tools are few, outside of the number of forge fires necessary. The steam hammers ranging from 1,500 pounds to 5,000 pounds weight of forging head are in general use, although the rapid forging press is now receiving considerable attention due to its reputed economy as well as the claimed superiority of its product.

(B-4 and 5)—The Pipe Shop and Structural or Boiler Shop.

The pipe shop, as well as the structural or boiler shop, should be conveniently located. Floor space for working

and storing materials is here a most essential factor. In both cases the total machinery required is small owing to the sameness of the work performed and the fact that the work is limited to a single field. In neither case is the product subjected to wear, breakage, etc., to so great an extent as to the products of the other shops. Both are important plant facilities, however, and the economies resulting from their work, as well as the prevention of shut-downs or delays, well warrants their being equipped with proper facilities and ground space. The machinery required is of standard design. In equipping the boiler shop, stability as well as capacity of the tools should be considered. In general, punches should have a capacity up to 1″ diameter through 1″ plate, and shears up to 1″ thickness.

(B-6)—The Roll Shop.

The roll shop is a very special repair facility devoted to the turning up of new and the redressing of worn rolls. Owing to the number of products from our rolling mills and the necessarily frequent roll changes, due either to wear or to changing over to another product, the number of rolls in stock has become a most important factor, so that this department should be thoroughly equipped not only with the necessary roll lathes, roll and neck grinders, etc., but also with proper handling facilities and roll storage racks in order that all rolls may be readily accessible. Some system of records is also essential to ensure that the proper rolls as well as the stock supply of rolls will be available.

(B-7)—The Locomotive Repair Shop.

The locomotive repair shop is becoming more and more important. The number of broad- and narrow-gauge locomotives necessary to take care of the inter-mill and department work, and the frequent inspection of each locomotive as required by law, as well as the repairs necessary demand recognition. While all repair parts can be finished by the different shops, it is desirable to have a separate building for preparing the engine to receive these parts. It is more convenient, when possible, to run the locomotive in as well

as out of the repair shop under its own steam. This means a considerable steam and smoke nuisance when blowing down, cleaning fires and starting fires, and would be objectionable unless done in a separate building. Also repair pits are necessary, and the tracks together with the pits make the floor space unavailable for other use.

Special Features.

1—Thermit Process. This can be used to quite an extent and to advantage in repair work, especially in repairing broken castings of considerable value which otherwise would have been scrapped. Necks have been built up successfully on broken mill pinions and with an increase in strength over the original casting. Locomotive frames have been welded, building a section at the point of fracture, increasing the strength of the frame. There are many heavy welds which can be made better by the thermit process than in any other way. The equipment required is negligible, but its successful use requires some experience.

2—Oxy-acetylene, etc., has proven its usefulness as a repair facility. The apparatus is portable and capable of both cutting and welding, and has been used in welding up seams on blast furnace stoves without removing any of the brickwork and no caulking was afterwards necessary. Locomotive frames have been repaired, stay bolts, fire-box and warped sheets can be cut off, cracks in fire-boxes have been welded. It has been used for welding up broken shafting, welding and building up teeth on gear wheels, welding defective pipe, welding up cracks in furnace shells, and stopping up rivet holes. In fact, its use has become very general and has resulted in marked economies in repair costs.

Portable rigs, such as the cylinder boring rig, crank-pin turning devices, drilling outfit, etc., are very successful where it is impracticable to do this work except in place.

Organization.

The results obtained and the extent to which delays are eliminated again depends upon the initiative of the mechanical and electrical departments. Complete and thorough

organization, with each branch knowing what part they will have to play, and with all branches harmoniously shouldering their responsibilities, forms the essential factor which through the use of the repair facilities makes possible the successful operation of a steel plant.

THE REPAIR DEPARTMENT OF A MODERN STEEL PLANT

Bertram D. Quarrie

General Superintendent, Newburgh Works, American Steel and Wire Company, Cleveland, Ohio

Mr. Hulst has called to your attention the various facilities which he considers as necessary adjuncts to a competent repair department of a modern steel plant finishing 90,000 to 100,000 tons per month.

It is a much discussed question as to whether it is advisable to make the necessary capital outlay to include all the facilities mentioned. The presence of an iron foundry at times proves a distinct loss through its operation, by reason of having a blast furnace off, and making it necessary to go into the market and buy pig iron for steel making, and consequently for the iron foundry. Furthermore the ordinary steel plant requires such a diversity of sizes and shapes in castings, that it is practically impossible to rig up the foundry to make quantity production, and hence low costs; there not being enough of one kind of casting to take advantage of this feature. When the pig iron production is curtailed as mentioned above, the ability to finish this pig iron in the various steel products would enhance the profits to the extent of the tonnage melted. And, in times of reduced demand for steel products it is invariably the case that it is possible to contract with iron foundries at advantageous figures for all requirements.

In a similar way, the operation of a steel foundry has at times its disadvantages; and whenever its operation in any way cuts down production of finished steel it is usually found to be uneconomical. The same applies to a roll foundry, and the extent of the diversity of products and the number of rolls required will usually determine the question of the advisability of its installation. If the varieties of product and

the number of sections are few, the installation of a roll foundry is usually inadvisable, as it is possible to contract ahead for rolls at reasonable prices to cover requirements.

With reference to the other facilities mentioned, namely: Brass foundry, pattern shop, machine shop, electric Repair shop, forge shop, pipe shop, structural or boiler shop, roll shop, locomotive repair shop, we think these are essential to the operation of a modern steel plant.

In the operation of a steel plant the efficiency and resourcefulness of the repair department is of prime importance. The methods by which work is carried on through the various departments must necessarily be of the best if the maximum production, at lowest cost, is to be obtained from operations. In the repair department the organization should be responsible to the Master Mechanic. All orders for material for spare and repair parts originate in his office. An outline of organization which we use, is as follows:

Master Mechanic, asst. Master Mechanic, Clerks,

Chief Electrician,	Blooming Mills Millwright,
Machine Shop Foreman,	Finishing Mills Millwright,
Structural Shop Foreman,	Iron and Brass Foundry Foreman,
Smith Shop Foreman,	
Pipe Shop Foreman,	Steel Foundry Foreman,
Pattern Shop Foreman,	Boiler House Foreman,
Carpenter Shop Foreman,	Locomotive Repair Foreman,
Bessemer Millwright,	Rigger Foreman.

In addition to the above mentioned organization, the roll shop foreman and master mason are considered a part of the repair department.

The continuity of operation of a steel plant, from the blast furnaces to the shipping dock, depends primarily upon the ability of this repair organization to anticipate the wearing out of parts, and be prepared at all times to make renewals in the shortest possible time when they become necessary. In order to insure this, a system of close inspection is absolutely necessary. The frequency of these inspections is dependent on the part of plant involved.

Inspections.

The Chief Electrician has in his department, motor inspectors whose duties require them to inspect every motor every day to see that the motors and controls are in proper shape. All cranemen in the plant are responsible to the Chief Electrician, and each one is made responsible for the condition of his crane, and required to report electrical or mechanical troubles to his superior. In addition to the reports from crane operators there is a weekly inspection of all cables and wire ropes in the plant by a rigger whose duties are the making of all splices and maintenance of proper slings, etc., for the riggers' department. Experience has taught us that it is necessary to change cables and wire ropes at certain stated intervals, especially those on cranes handling hot metal, and that it is best not to wait until broken strands or frayed ropes show danger signals.

In addition to above inspections of cranes, the safety department makes weekly inspections of cranes, and reports on condition of mechanical and electrical apparatus in addition to the condition of safety devices thereon. In case of repairs to motors, the changing of armatures, installing new bearings, or changing motor entirely, the Chief Electrician has a few riggers available, whose principal duties are in connection with this work for electrical department, and consequently they become skilled in handling electrical apparatus with little damage to motors and machinery. We have always felt that the placing of all cranemen in the plant under the electrical department gives the best results, due to chances of promotion of cranemen from one department to another, and also gives us men who are anxious to keep their cranes in good condition at all times.

Modus Operandi.

The department millwrights are representatives of the Master Mechanic in the various departments, with their quota of machinists, helpers, oilers, etc., to look after the mechanical end of the work. The method pursued in obtaining spare parts for any point in the plant is as follows: The

millwright will write a requisition on the stores department, and detail the part by pattern number (our pattern numbers are same as drawing number on which the part is detailed, with a suffixed letter to agree with letter on drawing) and the castings clerk will issue the part in question, the delivery either being direct to department or to the machine shop for finishing.

The stores department have under their control all castings in rough or finished state, and honor requisitions on presentation. A castings clerk keeps accurate record of all castings received and issued, and at all times has an actual inventory at hand for the information of the mechanical department, and as parts are issued will issue further requisitions on the various foundries or forge or structural shop to keep the stock of spare parts or repair parts at a predetermined minimum number. Periodical inspections of the stock of this material on hand, is made by Master Mechanic or his assistants, to be sure that changes made in design or material have not been overlooked, and that material on hand is of correct amount for ordinary renewals or repairs.

One of the most important features of a good repair department is a force of riggers able to handle their work to the best advantage, and keep the delays through break-downs to a minimum.

A good rigging department forms the nucleus of a mechanical organization, and from it we draw our oilers, machinist helpers, cranemen, etc. The rigging department looks after all the painting, the changing of cables and wire ropes, also transmission ropes, the loading and unloading of material other than that handled with a shovel or by hand, the cleaning of roofs, and all repairs requiring rigging of any kind. The continued handling of these various repair jobs has brought the rigging to a standard and there is little time lost in preparing for any one.

The millwrights in the various departments have under their control the locomotives, engines, pumps and hydraulic systems, all of which require close attention, and they order the repairs made through the department interested. The engines for heavy repairs are sent to the locomotive repair

shop, the hydraulic systems are taken care of by the pipe shop in case of leaks or renewals, while the packing of same is taken care of by a packing man in each department.

In packing the various points throughout a hydraulic system it often becomes necessary to renew packing that is apparently good, where its continued use might cause a serious delay of operations were it allowed to remain in service. This seems at times to cause excessive packing costs, but consideration must be taken of the loss in product, due to delays at inopportune times under stress of tonnage requirements later, particularly true of mills whose finishing capacity is less than the total steel making capacity, and whose maximum tonnage is necessary to fill orders for rolling.

The inspection of hydraulic lines and fittings at certain intervals is necessary in order to insure continued operation, and to guard against accidents occasioned through breakages. For a given condition in a mill it is advisable in the case of motor drives to have a series of motors which are interchangeable, making the carrying of excessive spares unnecessary. This same idea should be carried further with regard to feed rolls, bearings, drives and many other cases which could be brought up, duplicate, so far as is possible in order to keep down the spares necessary for continuous operation. The continued failure of any part gives rise to study of design or material which will obviate difficulties encountered, and places which formerly caused much annoyance gradually become as stable as the rest of the mill. The introduction of rolled sections for crane wheels, gears and the use of heat treated or special alloy steels for pinions, bevel gears and mill pinions, have done much to reduce work and worries of the repair department.

The use of special appliances such as are spoken of in Mr. Hulst's paper have also tended to reduce the responsibilities of the repair department.

The engineering department is of vital importance in connection with repair work, and all new work is carefully gone over by all concerned in the operation of same. Care is taken that the new work is of the best and most substantial, and with an eye to minimum cost of upkeep and repairs.

THE REPAIR DEPARTMENT OF A MODERN STEEL PLANT

H. L. Bodwell

Assistant District Manager, American Sheet and Tin Plate Company, Vandergrift, Pa.

The paper which we have just heard very clearly shows the important part which the Repair Department plays in the successful and economical operation of a modern steel plant.

It will give me great pleasure if, by adding a few remarks to what has already been said, and at the danger of some reiteration, I can add any evidence which will assist in drawing to this department the important consideration which it deserves.

The cost of labor and material in repairs, has been found to run from 8 to 12 per cent. of the cost above net metal in an open hearth plant, and from 20 to 25 per cent. in a blooming and bar mill. When it is considered that, in case of a breakdown occurring during operations, the cost of making the repairs is but a fraction of the cost due to loss of production, it can be readily appreciated that the Repair Department of any steel plant should be so organized and equipped with spare parts and appliances for doing the work as to be able to handle with despatch any emergency which may arise.

The extent to which it is advisable to carry the equipment of a given plant for doing its own manufacturing of spare parts and new machinery and the question as to the advisibility of installing steel, iron and brass foundries for the casting of parts for these purposes, is an economic problem for each individual plant management to solve.

Any works having an Open Hearth Department and not large enough to warrant a separate steel foundry can, in the writer's opinion, make with economy most of its own steel castings, especially those of a rougher nature, if room be

provided for a molding floor located somewhere under the open hearth ladle crane runway. If there are no suitable annealing furnaces available in some other department of the plant, facilities for annealing the castings must also be provided.

With the steel foundry located as above suggested, it is a simple matter to swing a ladle of any suitable heat of steel over the molds and after filling them, to teem the remainder of the heat into the ordinary ingot molds. It is the writer's experience that castings can be produced in this way for less than 2 cents per pound total cost.

It is not economical to maintain a separate steel foundry department unless steel castings be a part of the commercial output of the plant or unless the plant be large enough to consume a sufficient tonnage of castings to maintain a steel furnace of at least fifteen tons capacity in constant operation. This statement may be somewhat modified, however, if advantage is taken of some of the special furnaces of smaller capacity which have been perfected, such as the Carr or Wills or some form of electric furnace.

The advisibility of having an iron foundry is doubtful unless there be local requirements of sufficient extent to justify the necessary plant and organization. In most steel works the required tonnage of the smaller cast iron parts used in repair work is comparatively small, and the tendency is for these requirements to become smaller. A majority of the parts of all classes of rolling mill machinery formerly made of cast iron are today made of cast or forged steel on account of the greater reliability of the latter under severe stresses. Those parts which are necessarily of iron usually demand castings with special qualities more easily obtained from engine builders or foundries with long and expert experience in making the class of goods required.

If there be blast furnaces in connection with the plant, it will no doubt be found advantageous to make certain castings such as ingot molds, stools, floor plates, etc., from direct metal.

A brass foundry is of especial convenience in any plant on account of the immense number of small brass castings

used and such a foundry should be included in the equipment if the amount of castings required is sufficient to warrant the employment of expert supervision. While the plant necessary for casting brass is not very large or very expensive, it is of the utmost importance that the castings shall be of the highest quality.

Special Processes.

The utilization of special processes such as thermit welding, arc welding, autogenous welding and cutting by oxy-acetylene, blaugas and oxygen or liquid gas and oxygen, will be found of great advantage under certain conditions. The use of gears, pinions and spindles with the wearing faces treated by some special hardening process, such as the Stroch or Gebhardt, will result in longer life and reduced costs of upkeep in many cases. We have found it especially beneficial in the case of table roll pinions and spindles.

Thermit Welding.

Thermit welding has been found very useful and reliable on certain classes of repairs to steel castings and forgings. We have used it successfully many times in repairing broken locomotive frames without a single failure; also in casting new necks on blooming mill table rolls, repairing cracked gears, in several cases casting new necks on blooming mill rolls, casting new necks on bar mill pinions and various other jobs of more or less importance.

Arc Welding.

The application of the science of arc welding to the building up of the wearing faces of wornout spindles has been found especially useful. In some cases, notably in the repairing of blooming mill vibrating spindles, it is of especial advantage in forming a hardened face on the wearing parts which can be done by the use in the welding process of a special high manganese steel in conjunction with the soft steel commonly used. A spindle built up in this way has been found to last on an average of three to four times as long as a new untreated spindle.

Another useful application of arc welding is in the building up of worn areas on steel castings which have been in use, thus allowing the casting to be remachined to the original dimensions.

Autogenous Welding.

Autogenous welding, where used with discretion, has found some useful applications, resulting in large savings in cost and delays.

The writer has in mind one case in particular where one of the line shaft bearings of an ingot stripping crane had broken off from the end carriage of which it was an integral part. This was welded on again with an oxy-acetylene torch and a complete permanent repair made in four hours' time. Ordinarily a new end carriage would have to be installed, which in this case, on account of the location, would have taken two days and cost about five hundred dollars. On another occasion an oil box on a motor had been broken off. This was welded on satisfactorily in a very short time, saving the cost of a new frame.

This method of welding is also useful in making guards for machinery which present a very neat appearance and can be made in this way at lower cost than by riveting.

On the other hand this process of welding is not always absolutely reliable and good judgment must be used in deciding whether its use shall be attempted or not in any given case. A good weld can be made only by an experienced operator and means must be at hand, in the case of odd shapes, for preheating the parts to be welded and for annealing them after welding.

The cutting torch has possibly an even wider application in a steel plant than the welding torch. It is useful in cutting plates into various shapes, cutting and fitting structural work, wrecking steel structures, cutting out rivets or bolts, drilling holes in difficult places; cutting off links, bolts, nuts or tie rods, in taking machinery apart, and many other things too numerous to mention.

We have found it a useful equipment for the bar mill to have constantly at hand for cutting up cobbles which

occasionally occur. On a number of occasions delays of several hours have been avoided in this way.

Compressed Air.

The value of compressed air as an aid to the Repair Department, can scarcely be overestimated. It should be piped to all parts of the plant so as to be available at all times for any repair job. It can be used to advantage in running pneumatic tools, such as drills, chippers, riveters and hammers, and for many other purposes. Along crane runways it is especially useful for blowing the dust out of crane motors and for cleaning off the cranes. It is especially adapted to cleaning out motors in any dusty location and in the power plant for keeping generators free from dust.

Equipment of Repair Shops.

The writer has thought it best, in taking up the subject of equipment, to consider a plant of about the size of those with which he is most familiar; one having an open hearth and bar mill department capable of producing about 22,000 gross tons per month and finishing departments to take care of this output; in this case, sheet mills, annealing and galvanizing departments.

The repair department of a plant such as described will ordinarily consist of a machine shop, blacksmith and forge shop, electric shop, pipe shop, boiler and plate shop, carpenter shop and pattern shop.

The location provided for these shops in relation to each other and to the producing departments of the plant is of the greatest importance as affecting costs of upkeep and repairs. This feature should be given due consideration in the design of the original plant, and provisions made for future extensions in order that the shops may be enlarged as the plant grows and their efficiency as affected by accessibility from other departments be maintained.

Machine Shop.

The machine shop is the most important unit in the repair department and its design and equipment should

be such that it can take care of all ordinary break-downs which may occur and manufacture all spare parts of whatever size may be frequently needed.

In the design of the building, due consideration must be given to the important features of crane service over all heavy machine tools, lighting by day and night, heating and ventilation. Ample room should be allowed around machine tools and for erecting and assembling so as to avoid congestion.

The type of floor to be used is often a difficult question to solve. We have gotten by far the best results from wood blocks laid on top of concrete. This construction is very durable, can be easily repaired and is comfortable for the men to stand on. It is far superior to plank, cement, brick or steel.

Proper provisions should be made for wash and locker rooms, for sanitary closets and, when desirable, a room where the men can eat their lunches. These accommodations are equally necessary in all of the other shops to be described.

While it is generally desirable to have all machine work done in one central shop, there may be cases where economy will result by the location of smaller branch shops in isolated departments where some of the constantly recurring repair work, peculiar to those departments, may be taken care of, thus avoiding the delays incident to the transportation of parts back and forth to the main shop.

The kind and size, as well as the number of the various machine tools required, depends upon the character of work to be undertaken, on the extent to which it is deemed wise to go in the manufacture of the larger parts for spares, and whether it is desired to undertake new work or to confine it to repair work alone.

It is desirable to carry on more or less new work, thus rendering available a force of men for any extra amount of emergency work. In general it is not advisable to equip a shop for taking care of the largest work which may arise, as this involves an investment in large and infrequently

used tools. It is more economical to carry in stock such larger spares purchased from outside concerns.

The machine shop equipment for a plant of the size under consideration, might be given tentatively as follows:

Ten lathes of various sizes from 14″ to 60″ and with lengths of bed sufficient to take care of all requirements.

One 72″x72″ planer with 21 ft. bed equipped with two heads on cross rail and one side head.

One 48″x48″ planer with 10 ft. bed and two heads on cross rail.

Four shapers 20″ to 36″ strokes.

Two radial drills of 6 ft. radius.

One boring mill, 16′ capacity.

One boring mill, 4′ capacity.

Two gear cutters for cutting spur gears, bevel gears, and worm wheels.

One slotter.

One milling machine.

One keyseater.

Two bolt machines, one 2″ and one 3½″.

One cutting-off saw.

One centering machine.

One 300-ton hydraulic press for making press fits.

Also such additional or special tools as may be necessary in order to take care of any special requirements of the plant.

There should be a laying out table provided, and a bed plate in the floor for use in assembling and setting up jobs for portable tools.

It is important that a tool room of ample capacity be provided where all tools and supplies shall be kept, such as lathe and planer tools, drills, cutters, reamers, arbors, etc.

The tool room should be equipped with a universal tool grinder on which all lathe and planer tools shall be ground, also a twist drill grinder, cutter and reamer grinder and tool room lathe.

A heat treating and tempering furnace should be used for hardening and tempering all tools.

There should be attendants in this room, whose duty it is to keep all tools and appliances in first-class condition, and to give them out on a checking system.

The individual motor drive with variable speed motor and automatic controller is best adopted to the conditions in a shop of this character, where the use of many machines is more or less intermittent. It gives a powerful drive directly under the control of the operator and is well suited to obtaining a maximum output.

The remarkable development in recent years of high speed tool steel has rendered obsolete nearly every class of machine tool more than eight or ten years old, and it will generally be found a profitable investment to replace all such tools, if in constant use, with those of late design.

In our own shop several heavy duty machine tools have been purchased during the last few years, such as lathes, shapers, a planer, radial drill, gear cutter, etc. Tests made on these machines, compared with similar tests made on the old machines which they have displaced, have shown a superiority for the new machines of from 300 to 1000 per cent.

The advantage of these improvements in capacity is obvious when we consider how much time is saved on any repair job.

There should be a cost system in every shop whereby the labor and material on every job may be kept track of. This will be of great advantage in enabling those in charge to determine the best and most efficient methods to follow on various recurring jobs, whether the maximum production is being obtained from each machine, and will give data on which to base accurate estimates for new work.

A storehouse for castings should be maintained in conjunction with the machine shop where all smaller castings may be stored. Easy access should be provided to the yard where the larger castings are stored.

Blacksmith Shop.

The blacksmith shop may be considered, in a plant of this size, as a part of the machine shop. It is convenient in general to have it located under the same crane runway so that the forgings produced can be conveniently transported for finishing or loaded on to cars for transferring direct to other departments, if no finishing be required.

The equipment of a shop for the size of plant under consideration, should consist approximately of six single forges for hand work, one 600 lb. steam hammer, and one 2,000 lb. or 3,000 lb. steam hammer, or one 300 ton forging press. A shop of this size will turn out approximately 80,000 lbs. to 100,000 lbs. of press work, and 50,000 lbs. or 60,000 lbs. of hand work per month.

A steam hydraulic forging press is superior to a steam hammer, both from a forging cost and from a quality standpoint, provided there be a sufficient quantity of duplicate work to make possible the extensive use of dies.

There should be a rack for the storage of the supply of bar iron, within the department, and a shear for cutting bar iron.

All forgings should be analyzed before machining to check the heat analysis from the open hearth department. Physical tests should be made on all forgings of importance.

Electric Shop.

The electric shop should be located within the same building and under the same crane runway as the machine shop or at least in the immediate vicinity. It should be equipped with sufficient machine tools such as lathes, shapers, milling machines, drill press, etc., to take care of its own work where this work is of sufficient quantity to keep these machines employed enough of the time to warrant the investment involved.

All machine work of unusual size or nature which the electric shop is not equipped to handle can be done in the machine shop.

The electric shop should be amply equipped with such special tools as are necessary, such as an armature winding and banding lathe, coil winding machine, balancing machine, metal cutting band saw, shears, screw press, grinders and polishers, mica undercutting machine, etc.

A tool room is of advantage here as in the machine shop, where all small tools and appliances can be kept in order and given out on check.

Pipe Shop.

The pipe shop for a plant of this size should contain about the following equipment:

1—Pipe cutting and threading machine with range for 1/8″ to 2″ pipe.

1—Pipe cutting and threading machine with range for 1″ to 6″ pipe.

1—Pipe cutting and threading machine with range for 2½″ to 12″ pipe.

1—Cutting off and threading machine with revolving die head for cutting and threading bends with a range of at least 1″ to 6″.

1—30″ drill press.

All should be motor driven and reversible.

There should be a pipe bending machine, forge for heating pipe, bending table, pipe and machinists' vises, emery wheel, etc.

An overhead floor operated crane is advisable for serving the heavy pipe machines. There should be a tool room equipped with the various hand tools and appliances.

There should be a store room in connection with this shop, where all kinds of fittings and valves can be kept under the charge of a clerk who shall also have charge of the supply of pipe which should be kept in an easily accessible rack. He should keep a record of all supplies used by the shop for each department of the plant.

BOILER SHOP.

The boiler shop in a plant of this size can take care of all plate work and such structural work of a minor nature as it may be desired to fabricate locally. It will take care of the repairs to locomotive boilers, as well as all other boilers, and can, with advantage, have within its scope the construction of guards for machinery and the construction of other safety devices.

It should be equipped to manufacture and repair all such appliances, made up of boiler plate or structural material, as are used in the various departments of the plant in sufficient quantities to justify the capital investment in equipment.

This would include open hearth ladles, open hearth furnace pans, open hearth charging boxes, annealing boxes and galvanizing pots.

The shop equipment would include punches, plate and angle shears, bending rolls, riveting machines, a rivet furnace, circle shear, cornice break, cold saw, pneumatic tools and air compressor.

CARPENTER SHOP.

The carpenter shop, in order to handle with economy all work which may come to it, should have the following equipment:

A single surfacer, jointer, rip saw, cross cut saws, band saw, band rip saw, turning lathe, shaper, knife grinder, saw filing machine, mortising machine, tenoning machine, boring machine, etc.

There should be an exhaust system connected to each machine for removing all dust and shavings. This improves working conditions and reduces the fire risk.

There should be a lumber shed in convenient proximity to the carpenter shop.

PATTERN SHOP.

A well equipped pattern shop is of great importance to any plant of considerable size. Here all patterns of a

nature peculiar to the machinery in that plant can be made and stored ready for instant use in case of emergency.

Patterns of special design for use in emergency repair work can be quickly made, or existing patterns can be altered to suit different conditions or for greater strength.

This shop should be equipped with a lathe, jointer, band saw, rip and cut-off saw, shaper surfacer, trimmer, saw filing and setting machine, etc.

Fire-proof storage should be provided for pattern lumber and for the storage of patterns.

Organization.

While it is of great importance that a plant be equipped with ample facilities for carrying on its repair work, it is equally important that the personnel of the organization which has all of these facilities in its charge be of the highest quality obtainable.

At the head of this department would be the chief engineer or mechanical superintendent, supplemented by the electrical superintendent, whose importance is becoming greater and greater as the electrification of the modern steel plant becomes more and more complete, and by the superintendents or foremen of the other departments, each of whom should be a trained specialist in his own line.

The heads of this organization should be men of trained technical ability supplemented by wide practical experience. They should be equipped with a large portion of that native ingenuity which will enable them to solve the many unexpected and perplexing difficulties constantly arising in this business.

Above all they should have the executive ability which will draw forth that unselfish and coordinate effort from their subordinates so essential to the efficiency of any organization.

(Applause.)

THE USE OF TITANIFEROUS ORE IN THE BLAST FURNACE

Frank E. Bachman

General Manager, MacIntyre Iron Company, Port Henry, N. Y.

The MacIntyre Iron Company, owners of large deposits of titaniferous ore located in the township of Newcomb, Essex County, New York, decided to determine the commercial value of their ore by a practical test in a blast furnace. To this end it was proposed to erect a concentrating plant at the mines, haul the ore to the Delaware and Hudson Railroad station at North Creek, N. Y., and from there convey it by rail to the furnace selected for the test. At the request of the MacIntyre Iron Company, the writer visited several furnace plants available for the test and finally made arrangements with the Northern Iron Company for the use of their furnace located at Port Henry, N. Y. The arrangement made was that the furnace should be turned over to the MacIntyre Iron Company in operation on January 1, 1914, to be operated by the MacIntyre Iron Company for a period of six months, ending July 1; the lease was subsequently extended to August 1, 1914. The general supervision of the furnace operations was placed in my charge.

The furnace at Port Henry was selected for the reason that it has been operating for some years on a mixture of all-magnetic concentrates. The management and employees were in consequence thoroughly familiar with their use. Mr. George L. Shook, who had been in charge of the furnace operations for the Northern Iron Company for several years previous, acted as furnace superintendent during the lease of the MacIntyre Iron Company and no changes were made in the operating staff.

Preliminary Investigation of the Ore.

A preliminary investigation of the ore was made to determine the relative rapidity at which it lost oxygen compared

with Witherbee, Sherman & Co. Old Bed concentrates, which ore had been the base of the mixture used at Port Henry.

The analyses of the material used in this test were:

	Sanford Concentrates	Ilmenite	Old Bed Concentrates
Silica	2.26	1.72	4.90
Iron oxide (FeO)	33.19	39.21	....
Magnetic oxide (Fe_3O_4)	.....	.....	88.26
Ferric oxide (Fe_2O_3)	43.51	5.21	....
Alumina	4.52	.65	1.62
Titanic oxide (TiO_2)	12.34	49.10	.61
Manganese oxide (MnO)	.27	.55	.12
Vanadic oxide (V_2O_3)	.47	Trace	....
Chromium oxide (Cr_2O_3)	.19	Trace	....
Lime	.10	Trace	2.00
Magnesia	1.48	2.16	.33
Alkalies	Trace	Trace	....
Phosphoric anhydride	.007	.009	1.391
Sulphur	.104	.158	.04
Carbonic anhydride	.36	.47	....
Carbonaceous matter	.17	.13	....
Combined water	1.45	1.11	....
	100.421	100.477	99.271
Phosphorus	.003	.004	.624
Chromium	.134	Trace	....
Vanadium	.260	Trace	....
Manganese	.209	.426	.09
Titanium	7.40	29.46	....
Metallic Iron	56.29	34.13	63.90
Nickel	Possibly a trace; tests doubtful.		

The test was made by placing samples of Old Bed concentrates, Sanford concentrates and ilmenite, separated mechanically from Sanford tailings, in an electric ignition furnace. The temperatures were determined by placing a thermo-couple outside of the containing tube and deducting from the temperature indicated 50° F., which was found to be the difference between the temperatures outside and inside of the tube. The first experiment was to determine the temperature at which each of these ores began to give up oxygen to pure carbonic oxide and also the temperature at which chemical action began to be rapid. The results were:

Old Bed concentrates,	action began at 875-900° F.,	rapid at 1100° F.
Sanford concentrates,	" " " 875-900° F.,	" " 1050° F.
Ilmenite,	" " " 825-850° F.,	" " 975° F.

This test indicates that the titaniferous ore begins to reduce at no higher temperature than that at which the mag-

netic ore begins to reduce and that the action on the ilmenite begins at a somewhat lower temperature.

A sample of gas was then drawn from the blast furnace from a point 21.5 feet below the tunnel head. This corresponds approximately with 10 feet below the average stock level and with a temperature in the furnace on 1150° to 1175° F.

Samples of Sanford concentrates, Old Bed concentrates and ilmenite were then placed in the combustion furnace tube, the tube filled with gas drawn from the furnace, and brought to a temperature of 1150° F. The furnace gas was then passed over these samples at the rate of 45 liters per hour under a head of 16.5 inches of water. The current was passed from right to left for the first hour, and from left to right for the second hour. Under these conditions the Sanford concentrates lost 43.51 per cent. of the total oxygen combined with its iron, the Old Bed concentrates lost 18.54 per cent. of its oxygen, the ilmenite 4.82 per cent. This test demonstrates that in the top of a furnace the Sanford concentrates lose in the same unit of time more than twice as much oxygen as non-titaniferous magnetic concentrates. The loss of oxygen from ilmenite was so small as to indicate that probably only the magnetite which was not perfectly separated from it was reduced.

The third experiment was to determine the relative action of carbon on the ores at the temperature at which reduction takes place by direct combination of carbon with the oxygen in the ore, namely 1300° F. and above. For this determination equal weights of ore and coke were placed in the ignition tube, the air in the tube replaced with carbonic oxide, and the temperature then brought to 1300° F. The temperature was gradually raised to 1450° F. through a period of two hours, during which time the atmosphere of carbonic oxide was maintained in the tube. The Sanford concentrates lost 51.81 per cent. of their oxygen, the Old Bed concentrates 22.66 per cent. and the ilmenite 33.81 per cent. These results demonstrate that Sanford concentrates lose oxygen more than twice as rapidly as non-titaniferous magnetic concentrates, and ilmenite 50 per cent. more rapidly. This

experiment, however, is of no special value as it does not correspond with any blast furnace reaction, in that solid carbon never begins to react on the oxygen of the ore until a large proportion of the more easily removable oxygen has been removed by the action of carbonic oxide.

Preliminary Investigation of Slags.

A further preliminary investigation was made of the fluidity and melting points of slags of composition similar to those which were made at Port Henry in the regular furnace operations and of slag in which a portion of the silica was replaced by titanic acid.

When the investigation was conceived, it was supposed that conditions and apparatus in which the constituents of slags similar to those that will be produced in a blast furnace when smelting Sanford concentrates with Witherbee, Sherman & Co. concentrates, using for the flux a mixture of equal parts of the calcite and dolomite in use at Port Henry, would be obtainable. It was proposed to melt the mixtures which produce slags corresponding to those that will be made when using one-eighth, one-fourth, three-eighths, one-half, five-eighths and all Sanford concentrates in a mixture, together with a standard slag similar to the slag produced in regular practice when using 100 per cent. Witherbee, Sherman & Co. concentrates.

It was hoped to be able to melt the mixtures and bring them to the supposed temperature of the blast furnace hearth, holding them at that temperature long enough to observe their characteristics while melted, and then to pour them into runners under similar conditions in order to observe their flow, the length of the flow, size of the chilled section, etc. From the data obtained, conclusions were to be drawn regarding the probable result to be expected as far as the test corresponded to furnace conditions.

My conception of the formation of a blast furnace slag is that at a point approximately 25 feet above the tuyeres the minerals which have the lowest melting point in the ore begin to melt, then the free SiO_2 combines with FeO and with the

melted minerals forms a fusible slag somewhat similar to heating furnace cinder. This slag flows down over the pieces of lime and coke, and when it reaches the hotter section of the furnace, the FeO is gradually reduced to Fe and replaced by CaO or by CaO and MgO from the lumps of burned stone. In front of and immediately above the tuyeres the coke ash is set free and combines with the slag produced above, and a portion of the lime not completely fluxed often passes below the tuyeres and is absorbed in the bath of slag in the hearth. If this conception is correct, it is of course impossible to duplicate the process. The only thing to be studied, therefore, were the slags after they had completely formed. Even in this I was not entirely successful. Besides very valuable aid in this work the Titanium Alloy Manufacturing Co., Niagara Falls, N. Y., kindly gave me all of the facilities available at their plant in apparatus, assistance and advice. For this I am under many obligations to Messrs. Thompson and Barton.

After several experiments with various types of coke and electric furnaces, it was decided to use crucibles turned from solid electrodes, in order to prevent contamination from the clay of graphite or other crucibles, and a carbon resistance furnace having a variable voltage, melting two charges per heat.

The furnace consisted of two 8-inch electrodes between which the crucibles, surrounded by small lumps of broken electrode, were placed. A mixture of 500 grams of the materials which would produce the slag desired was placed in each crucible. The mixture in one crucible made the standard slag, and that in the second the titaniferous slag. The mixtures were calculated to make slags corresponding to acidity of SiO_2 plus Al_2O_3 plus three-fourths TiO_2, equaling in all 47 per cent. The materials used were quartz rock burned lime, commercial alumina, rutile, magnesia from three sources, and calcium sulphide. The quartz rock only was analyzed. Owing to an error in the determination of the SiO_2 contents of the quartz rock, almost all of the slags were more acid than was desired. There are some reasons to suppose, however, that TiO_2 is not so much of an acid as

figured, so the excess of acidity is probably more apparent than real.

It was found to be impossible to bring the contents of both crucibles to even apparently the same temperature, or even to approximately measure the temperature with Seger cones, which were the only means available. But persons accustomed to observing high temperature, in some cases, guessed the heat at fully 1600° C. At this heat a No. 20 Seger cone held above the melt bent slightly, indicating 1500° C., with every indication that the lower portion of the crucible was decidedly hotter.

Table 1 gives the analyses of the slags, their specific gravity, the length each ran and their melting points.

After melting, the mixtures were poured into two runners made of the same material and having the same fall. Having completed the tests 1 to 7 inclusive, others with varying acidity and proportions of CaO and MgO were made.

Slags No. 5 and 6 were poured into damp sand runners which had a tendency to chill them more rapidly than the subsequent pours made in runners of graphite dust. The fal of the sand runners was 1 inch in 1 foot, of the graphite runners 1 inch in 2 feet 6 inches.

Results of Slag Experiments.

The conclusions drawn from these tests are:

1. Assuming the pouring heats were approximately hearth temperature, slags corresponding to those produced when using one-eighth and one-fourth of the mixture of Sanford concentrates are more fluid than those produced at Port Henry. They were as rapidly melted in the crucible, did not stick to a cold rod more or less than standard slags, and showed no indications of greater viscosity.

2. The slag No. 3 contains TiO_2 corresponding to more nearly five-sixteenths than to three-eighths Sanford concentrates. This slag also was better in every way than the non-titaniferous slag melted beside it.

3. Slag No. 4 corresponding to one-half Sanford concentrates, was both sticky and mushy in the crucible and when

poured refused to run. The temperature at which this slag was poured was apparently higher than that at which the other slags were poured. Reference to its acidity shows it to be decidedly more basic than those referred to above. When smelting is boiled and a scum, which refused to melt, formed on its surface. Supposing an error had been made in weighing the materials for this slag, other slags were made up, 4*a*, 4*b*, 4*c* and 4*d*, with varying acidity and varying lime and magnesia proportions. These will be referred to later.

4. Slag No. 5, corresponding to five-eighths Sanford concentrates, showed rather more TiO_2 than it should. It melted freely. A slight scum formed on the surface but it quickly disappeared as the heat was raised. It stuck to a cold rod more than any of the slags referred to above and when poured flowed freely for a short distance and then set very suddenly. It did not have the fluidity of the standard slag melted at the same heat.

5. Slag No. 6, corresponding to 100 per cent. Sanford concentrates, showed all the characteristics of No. 5 except that more scum formed on its surface and the scum did not entirely disappear on raising the heat. The slag felt sticky when stirred with an iron rod and adhered to the rod. From a furnace man's point of view it was an undesirable slag which, if possible to be worked at all, would be likely to give continuous trouble.

To further investigate the slag corresponding to one-half Sanford concentrates, slags 4*a*, 4*a* plus 5 per cent. fluorspar, 4*b*, 4*c* and 4*d* were made. In weighing the materials to make these slags the same amounts of Al_2O_3 and TiO_2 were used, in fact they were weighed without change of the weights on the balance. The variation in the percentage of Al_2O_3 is, therefore, peculiar. The results were:

(a) 4*a* and 4*a* plus 5 per cent. fluorspar. 4*a* showed a slight scum on the surface which cleared up quickly. 4*a* plus 5 per cent. fluorspar melted clear. Neither stuck to a rod. 4*a* was more fluid than any slag melted previously, excepting slags 1 and 2. 4*a* plus fluorspar was decidedly the most fluid slag made. Had the runner been long enough, it would have flowed 6 feet or more.

(b) 4*b* and 4*c*. All the constituents of these slags as weighed were identical, excepting the CaO and MgO. Both of these slags gave off gas and boiled when melted, seeming to indicate that a reduction was taking place. 4*b* was viscous, stuck to a rod, and had a heavier scum which would not clear up. 4*c* was fluid in the crucible and the slight scum which formed cleared up. This slag did not stick to a rod and when poured it looked cooler than 4*a* and was slightly less fluid. 4*b* was a poor slag. This test indicates that increasing MgO increases fluidity.

(c) 6*a* and 6*b*. The same weights of all materials, excepting lime and magnesia, were used. Both slags melted very hot and boiled in the crucible. 6*a* was mushy, stuck to the rod more than 6*b*, had a heavier scum, ran slowly, and was a decidedly poor unworkable slag; 6*b* showed the same characteristics but was less viscous. It also was a poor unworkable slag.

For the purpose of determining the effect of titanic slags on sulphur, a mixture corresponding to 4*a* containing 3.50 per cent. and 4*d* containing 5.20 per cent. calcium sulphide was melted. After melting, 350 grams of cast iron borings were added on the top of each mixture. It will be noted that in each case one-half the calcium sulphide was apparently lost, a loss which shows in all the slags whether titaniferous or not. (A subsequent analysis of the calcium sulphide proved it to be but 50 per cent. pure.) It would be expected that both of these slags would absorb sulphur from iron. The results obtained, however, were remarkable and unexplainable. The analyses are as follows:

	Si.	C.	Ti.	S.
Borings before melting	2.79	3.05	0.018	0.078
Borings after melting, 4*a*	1.45	5.37	1.62	0.026
Borings after melting, 4*d*	1.04	4.36	1.39	0.023

As the borings chilled the slag and were melted in an oxidizing atmosphere similar to conditions existing in a puddle furnace, the loss of Si may be explained by assuming that the action in the crucible was the same as in a puddle furnace. The absorption of carbon may have been due to excess heat resulting in absorption of carbon from the cru-

cible. I, however, am not aware that such an absorption has ever been pointed out. The reduction of sulphur with slags of the acidity and sulphur contents given was to be expected. The reduction of Ti was wholly unexpected. From all of our knowledge of Ti, its strong affinity for oxygen and its formation temperature, it is to be expected that it will not reduce as readily as silicon. If, therefore, the temperature of this experiment was high enough to reduce Ti from a slag, it was to be expected that silicon would also be reduced. Should a reaction similar to the above take place in the blast furnace, one cannot foretell the results on the product or on the furnace work.

Melting Point: The melting point of none of these slags was excessive; it corresponded to that found previously in the case of somewhat similar slags. The variations among the titaniferous slags are no greater than among the non-titaniferous ones. Professor Hunter, who determined the melting points, indicates that at the melting temperature, slags from the blast furnace, whether remelted or not, showed greater fluidity than the artificial slags.

Raw Material Difficulties.

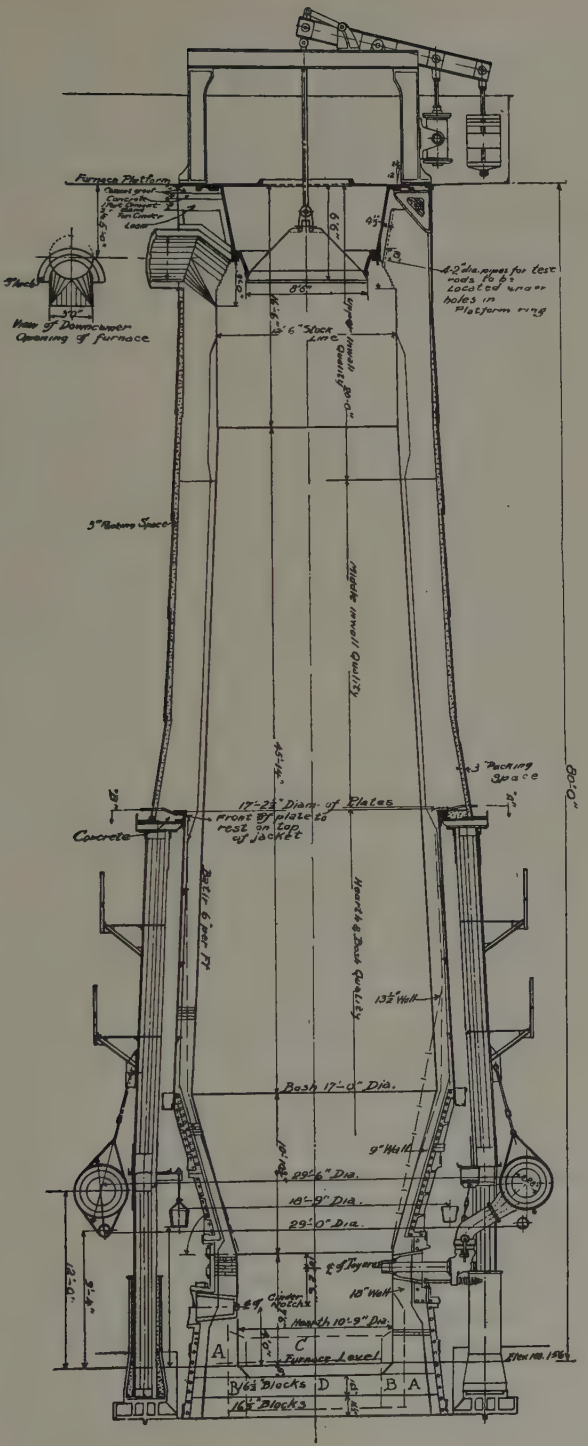
When the test was undertaken it was the expectation that the MacIntyre Iron Company would begin to deliver their Sanford concentrates to the furnace not later than February 1, and be able to continue its delivery throughout the period of the lease. The concentrating plant at the mines, however, proved to be a failure and it became necessary to either abandon the test or make other arrangements for concentrating the titaniferous ore. This concentration was then made by Witherbee, Sherman & Co. in their concentrators at Mineville, N. Y., the crude ore being shipped to Mineville and the concentrates from Mineville to the furnace at Port Henry, N. Y. The original expectation was that the mill at the mines would be in operation about November 1, 1913, and that there would be a considerable supply of concentrates accumulated previous to the winter fall of snow. These concentrates were to be transferred to

the railroad at North Creek, N. Y., a distance of 30 miles, by steam tractors drawing sledges over the snow. The concentrating mill, however, was not completed till about February 1; the time lost in testing the mill further delayed operations. The crude ore to be concentrated at Mineville was then transferred for a distance of 12 miles by tractors and teams to the end of the State road, where it was stored until the snow melted. From this point it was conveyed to North Creek on automobile trucks. As a result of these delays a sufficient ore supply for continuous operation was not delivered to the furnace until June 1, and a sufficient ore supply for a continuous operation of the furnace on titaniferous ore was only available from June 1 to August 1.

Some years previous to undertaking this test, several hundred tons of crude ore had been transported by wagon to North Creek, where it remained. This ore was shipped to Witherbee, Sherman & Co. in January and concentrated in their No. 2 mill, which was designed for the concentration of Old Bed concentrates. This small supply of ore became available about the time the attempt was made to concentrate ore at the mines, and when it was expected a continuous supply from the mines would be available before it was all used in the furnace. The failure of a continuous supply of ore necessitated discontinuing the test after the use of titaniferous ore for the period between February 6 to 17. Between February 17 and June 3 there was no further use of the ore. On June 3 its use was resumed and continued till July 29 when under the terms of the lease it was necessary to remove it from the mixture in order to enable the MacIntyre Iron Co. to return the furnace to the Northern Iron Company on August 1 in the same condition as received, ordinary wear and tear excepted.

Description of Blast Furnace.

The furnace used in this test was 80′ high, 17′ bosh, 10′ 9″ hearth, 12′ 6″ stock line, 8′ 6″ bell. The height of the bosh was 11′ 10¾″ above tuyere center, cinder notch 4′, and tuyeres 6′ 6″ above hearth level. Bosh batter 74°, inwall



Furnace Platform
Concrete
8'6"
6'9"
4-2" dia. pipes for test rods to be located under holes in Platform ring
View of Downcomer Opening of furnace
18'6" Stock Line
Upper Inwall Quality
80'-0"
9" Packing Space
Middle Inwall Quality
45'-14"
3" Packing Space
17'-2½" Diam. of Plates
Front of plate to rest on top of jacket
Concrete
Batir 6 per Ft
Hearth & Bosh Quality
13½" Wall
Bosh 17'-0" Dia.
9" Wall
29'-6" Dia.
18'-9" Dia.
29'-0" Dia.
℄ of Tuyeres
18" Wall
Cinder Notch
Hearth 10'-9" Dia.
C
A
Furnace Level
B/6½" Blocks
D
B
A
16½" Blocks
12'-0"
80'-0"

batter .6″ per foot. It was of semi-thin wall construction, in that the bosh was constructed of cast iron coil plates, water circulating through the coils. The thin-wall section extends to 19′ 4″ above the bosh line. This section is built of one-inch steel plates and is cooled by sprays at the top. A row of cooling plates is inserted in the wall above the thin-wall section, these plates being placed overhanging the bosh extension, reaching to 4½″ from the face of the brick work. The lining on the bosh walls is 9″ thick, in the thin-wall section 13½″, the inwall being 27″ thick, the tuyere circle 18″. There are 12 tuyeres 30° center and one cinder notch. The stoves consist of 3 two-pass stoves, 16′ x 80′, and 2 three-pass stoves, 20′ x 96′; the two-pass stoves have 19,000 sq. ft. and the three-pass stoves have 40,000 sq. ft. heating surface each. There are five water tube boilers rated at 1550 H.P. The blowing engine is a General Electric turbo blower having a rated capacity of 22,500 cu. ft. of air at 25 lbs. pressure with 150 lbs. steam and 28 inches vacuum. There is an ample equipment of pumps for the water supply. The type of furnace described has been in use at this plant since 1904; the furnace itself, however, was rebuilt and first blown in September 23, 1912. It had been in continuous operation until it was turned over to the MacIntyre Iron Company. The blast had not been satisfactory. The old stack which it replaced was 10′ hearth, 16′ 6″ bosh, 11′ stock line, 8′ bell, 69′ 6″ high. It had operated with a fuel consumption averaging 200 lbs. less than the average of the present blast of the furnace. The increased fuel consumption seemed to be largely due to a decided tendency of the furnace to hang and slip. Throughout the blast there was a continuous fight to prevent the furnace from scaffolding and to remove scaffolds which formed. This fight continued during the entire period of the MacIntyre Iron Company's operation.

All ores used for several years previous to and during the test run were magnetic concentrates. These ores, other than the titaniferous ores, were produced (6 miles from the furnace) by Witherbee, Sherman & Co. at Mineville, N. Y.

Typical analyses and sieve tests of the Mineville ores are as follows:

Analyses	Barton Hill Concentrates	Old Bed Concentrates	Harmony Cobbed	Harmony Middlings
Iron	63.45	64.68	62.55	28.13
Silica	10.15	4.65	10.40	41.85
Phosphorus	.028	.63	.124	.205
Manganese	.07	.11	.07	.07
Alumina	.99	1.59	1.73	5.39
Lime	.40	2.45	.70	2.60
Magnesia	.39	.42	.41	1.35
Titanic acid	.91	.00	.00	.00
Sulphur	.00	.045	.061	.048

Sieve tests:	Barton Hill Concentrates	Old Bed Concentrates	Harmony Cobbed
On 8 mesh	32.70	25.11	26.05
On 20 mesh	28.70	40.44	32.85
On 40 mesh	19.60	15.89	18.20
On 60 mesh	8.10	6.31	7.90
On 80 mesh	3.90	3.21	4.20
On 100 mesh	.65	1.06	1.50
Through 100 mesh	6.00	7.97	8.80

As is well known, a mill for the concentration of magnetic ores must be adapted to the ore to be concentrated. The Sanford crude ore shipped to Mineville was concentrated in three different mills: No. 1 and No. 2 mills, which were built for the concentration of Old Bed ore, and No. 4 mill, which was built for the concentration of Barton Hill ore. It was found that none of these mills were suitable for the concentration of Sanford ore, the heads produced being decidedly lower in iron and higher in titanic acid than they should have been, and the tailings at the same time being too high in iron. The best work was done by the No. 2 mill, the ore from which was used in the furnace during the short test run in February.

Analyses and sieve tests of the ore produced by the Sanford mill and mills No. 1, No. 2 and No. 4 are as follows:

Analyses of Sanford Concentrates	No. 2 Mill	No. 2 Mill	Sanford Mill	No. 1 Mill	No. 4 Mill
Iron	56.46	55.95	54.11	54.82	55.37
Silica	2.35	2.55	2.50	2.70	3.65
Phosphorus	.004	.003	Trace	.004	.003
Manganese	.20	.18	.17	.22	.19
Alumina	3.68	3.98	4.60	4.98	4.85
Lime	.45	.12	.45	.15	....
Magnesia	.95	1.62	1.79	1.87	1.73
Titanic acid	11.83	11.80	13.78	13.98	12.35
Vanadic oxide	.415	.40	.629	.546	.638
Chromium oxide	....	.244	.35	.285	.386
Nickel oxide	.052	.049	.054	.047	.053
Sulphur	.137	.119	.123	.137	.170

Sieve Tests	No. 2 Mill	Sanford Mill	No. 4 Mill
On 4 mesh	3.83	1.15	.00
On 8 mesh	45.79	33.76	26.22
On 12 mesh	31.30	41.20	38.96
On 20 mesh	1.23	1.12	3.41
On 40 mesh	8.42	10.59	5.59
On 60 mesh	3.08	5.08	10.33
On 80 mesh	.85	1.77	4.81
On 100 mesh	1.75	1.72	3.91
Through 100 mesh	3.70	3.61	6.67

The coke used, for the most part from the Connellsville field, was of good chemical composition, rather dense in structure and inclined to grind and break. The sulphur contents varied between .85 to .95, averaging .90.

The fluxes consisted of dolomite from a quarry operated by the furnace; this was extremely variable in silica and alumina contents and excessively high in alumina. It was crushed to pass a 4″ ring.

The calcite was waste from marble quarries and mills in the district of Rutland, Vt. It was remarkably uniform in composition and the quality was high grade.

Typical analyses are:

	Dolomite	Rutland Calcite
Silica	3.25	1.41
Alumina	2.30	.70
Lime	31.76	53.71
Magnesia	17.72	1.10
Phosphorus	.007	.008

The gas from the furnace is cleaned through a 18′ x 18′ dust catcher and from there passes through a 15′ gas washer, designed by the writer. In appearance the washer is identical with that of the old type of dust catcher. The gas enters tangentially; water is supplied through water seals at the top and under the gas inlet connection; water from the seals flows over the interior of the walls. The gas is taken off through a central outlet pipe near the bottom of the straight section. The tangential inlet pipe gives the gas a swirling motion through the body of the washer, causing the dust particles to impinge against the sheet of falling water on the walls which then carries them away. A water seal is provided at the bottom. The operation is continuous, no labor is required as the dust is carried off by the wash water. Its

operation is so successful that almost no stove cleaning is required.

The Old Bed concentrates are crushed for concentration to pass a 0.25 inch round opening. They break into rounded particles which have a very decided tendency to run ahead in the blast furnace. Their composition is almost uniform, there being very little variation in their iron and silica contents from day to day.

The Harmony cobbed ore is concentrated by a series of cobbing separations followed by fine grinding. The larger pieces of this ore, those which lie on 8 mesh, vary in size from 2 inches to one-eighth inch in diameter. The crystals are not as rounded as those of the Old Bed concentrates and it has less tendency to run ahead in the furnace. It is extremely variable in composition, the iron and silica varying from day to day as much as 5 per cent. The bin system at Port Henry is such that the ores cannot be held long enough for analysis before charging. On this account it is very difficult to keep the slag composition uniform.

The concentration of Barton Hill ore is made in very much the same manner as the Harmony. The mill is better equipped, resulting in less fines being made.

Harmony middlings are used only to increase the slag volume. This is the coarsest ore used; it consists of the tailings left from the first cobbing in producing Harmony cobbed ore. No sieve test of this ore has been made. More than 50 per cent. of it will lie on a ¼ mesh sieve, the larger pieces passing a 2 inch ring. In composition it will vary from 28 to 45 per cent. in iron and from 25 to 45 per cent. in silica.

The Sanford concentrates from the various mills are very uniform in composition, although during the whole period of their concentration the operation was experimental. No sieve test was made of the ore produced by the No. 1 mill.

Previous to the furnace being taken over by the MacIntyre Iron Company it had been hanging and slipping, refusing to carry a full burden. The management, in endeavoring to remove the scaffold, replaced the tuyere breasts with shorter ones. It was noted that after this change the breasts

and the lower sections of the bosh jacket were decidedly hotter than normal. On January 3 the bosh walls were drilled and it was found that at a point 7 feet above the tuyeres the maximum thickness of brick and carbon coating on the bosh plates was 3½ inches, the minimum being 1¾ inches. The furnace previous to this time had been operated on a more acid cinder than had been the practice at Port Henry for several years. The tuyere breasts were not changed, but the tuyeres were lengthened. The furnace was run on a basic slag to thicken the carbon coating. As it had been currently reported that titaniferous ore built rapidly on the boshes, it was assumed that the short tuyere breasts would be a help in preventing building. Previous to beginning the use of titaniferous ore, it was found that the carbon coating on the boshes had built on so that at the beginning of the test run it was from 6 to 11 inches.

The First Run in February.

Foundry iron was made during the February run. The mixture previous to the use of Sanford ore was: Old Bed concentrates, ten-sixteenths; Harmony cobbed, four-sixteenths; Harmony middlings, two-sixteenths. One-sixteenth of Sanford ore was charged, replacing one-sixteenth of Old Bed concentrates, the burden being:

Ore	9,760 lbs.
Ferro-manganese cinder	120 lbs.
Coke	7,050 lbs.
Calcite	1,220 lbs.
Dolomite	1,220 lbs.

When this charge was made the furnace was hanging and slipping, although the pressures were not high. Within 36 hours of the change reaching the tuyeres, the furnace stopped slipping and throughout the 10 days of the test ran more uniformly than it had for several months previous. One-sixteenth of Sanford ore was continued from February 7 to February 11 when it was increased to two-sixteenths, the mixture then being: Old Bed concentrates, nine-sixteenths; Harmony cobbed, three-sixteenths; Harmony middlings, two-sixteenths; Sanford concentrates, two-sixteenths. The in-

creased amount of Sanford ore made no change in the operation of the furnace other than that it gradually gained in heat. The burden over this period was gradually increased. At the expiration of the test it was:

Ore	10,200 lbs.
Ferro-manganese cinder	140 lbs.
Coke	7,050 lbs.
Calcite	1,800 lbs.
Dolomite	600 lbs.

It was noted that immediately on the one-sixteenth of Sanford ore reaching the tuyeres the cinder became more fluid. On increasing it to two-sixteenths the fluidity increased so that it was impossible at times to stop the notch without slacking the engine. At the same time the scouring qualities of this cinder became apparent in the rapid cutting away of the runner from the cinder notch. The chilled samples of cinder and the cinder in the runner became decidedly stony and dark, having the appearance of being more acid than the analysis indicated. The silicon in the iron was somewhat less than was expected from the apparent heat of the cinder and the appearance of the running iron. The iron was not as fluid as it had been previously, its fluidity being decreased about equivalent to an increase of one-half per cent. of silicon. The sulphur contents dropped slightly, the indications seemed to be that the presence of titanic acid in the slags was either reducing sulphur, or that the slags were actually more basic than their composition indicated. After increasing Sanford ore to two-sixteenths the cinder did not follow the iron while casting without considerable pricking and the first cinder which flowed with the iron seemed to be more viscous than normal. For several casts no cinder at all followed the iron and it was presumed that the furnace hearth was filling with titaniferous compounds. The titaniferous ore was then reduced to one-sixteenth and 4 bevel-nosed tuyeres introduced with the idea of cutting out the hearth. The iron notch, however, had not raised and tapping was no harder than normally. Immediately after the reduction of the titaniferous ore and before it reached the hearth, the iron notch returned to normal with a free

flow of cinder. The two-sixteenths of Sanford ore were put back after 18 hours and there was no return of indications of hearth building. The tuyere breasts and lower sections of the bosh jacket were continually becoming hotter. On February 13 the cinder broke through a 2¾ inch hole under No. 3 tuyere. A similar hole had been left in the jacket under each tuyere, to be used in case cinder could not be tapped from the furnace at any other place. A similar break-out occurred some six hours later, and on the succeeding day a third occurred over the iron notch through a joint in the tuyere jacket. The bevel-nosed tuyeres were then removed and No. 1 and No. 12 tuyeres plugged. Twenty-four hours later the titaniferous ore was removed from the furnace, the available supply having been used up. The proportion of calcite was increased on February 16 to three-fourths, and the dolomite reduced to one-fourth. It was noted that when this change came down the excessive fluidity of the cinder was materially changed. It still remained, however, more fluid than normal cinder.

The weather conditions throughout this run were abnormal, the thermometer registering continually from 10° to 30° below zero. These weather conditions rendered the prompt handling of cinder ladles and iron trucks impossible. Throughout the entire period both flushing of cinder at the proper time and casting at the proper time were impossible. As a result cinder was carried abnormally high. The cinder break-outs were probably due to a combination of the excessive fluidity, the short tuyere breasts and the fact that cinder had been carried up to and above the tuyeres almost every cast. Immediately on the removal of the titaniferous ore the longer tuyere breasts were replaced. Reference to the slag analyses will indicate that the titanic acid content was not uniform and in some cases the titanium in the iron, plus the titanium in the slag does not account for all of the titanium charged.

After this run the bosh walls were again drilled and their thickness found to range from 3½ to 9 inches. The material drilled through was the normal carbon deposit. The lesson learned was that there would be more danger from the exces-

sive fluidity of titaniferous slag than from its being viscous and sticky. In fact everything out of the ordinary that occurred was entirely at variance with what had been expected and guarded against.

Table 2 gives the consecutive analyses of the iron produced during this period.

The full analyses of the slag made on February 9 and 11 are as follows:

Silica	33.40	31.70
Oxide of iron and alumina	13.90	14.90
Titanic acid	3.90	3.00
Lime	38.60	40.30
Magnesia	9.54	9.21
Sulphur	1.60	1.60

The temperatures of the slag and iron as they flowed from the furnace, as observed by Joseph F. Cullum of the Bureau of Mines, are given in Table 3.

The iron temperatures are not very satisfactory, for owing to a film of oxidized material on the iron, it was almost impossible to obtain true observations. It was noted that after the iron ran into the chills its surface became dark, its appearance being similar to that often noted in the manufacture of foundry iron, generally assumed to be due to a separation of graphite. At times, when the iron ran slowly, this separation was very distinct on the pool between the skimmer and the dam. A sample of this material was taken and its composition found to be:

Iron as Fe_3O_4	17.68
Silicon as SiO_2	38.40
Manganese as Mn_3O_4	13.28
Carbon as C	1.30
Titanium as TiO_2	26.72
Vanadium as V_2O_3	.30
Sulphur as SO_3	.34
Gain on ignition plus carbon	2.28
	100.30

The Second Experimental Run.

The use of titaniferous ore was resumed on June 3. Previous to its use the furnace was operated for the production of malleable iron. On changing from foundry to malle-

able iron the furnace scaffolded badly and during the last 10 days in May its entire production was off-grade iron. It had not entirely recovered when Sanford ore was charged. The mixture introduced then was Harmony cobbed, ten-sixteenths; Barton hill, three-sixteenths; Old Bed concentrates, one-sixteenth; Sanford concentrates, two-sixteenths. The burden was

Ore	9,880 lbs.
Ferro-manganese cinder	140 lbs.
Coke	7,130 lbs.
Calcite	2,685 lbs.
Dolomite	895 lbs.

The furnace continued hanging and slipping during June 3 and 4. On June 6 Sanford ore was increased to three-sixteenths, the mixture being: Harmony cobbed, nine-sixteenths; Barton Hill, three-sixteenths; Old Bed, concentrates, one-sixteenth; Sanford concentrates, three-sixteenths. The ore burden was increased to 10,000 lbs. On June 6 the furnace hung badly, in fact did not settle except on a full stop up to 10:30 P. M., after which it straightened away and settled regularly, coincident with a reduction of the burden to 9,760 lbs. of ore. On June 9 Sanford ore was increased to four-sixteenths, the mixture being: Harmony cobbed, seven-sixteenths; Barton Hill, four-sixteenths; Old Bed concentrates, one-sixteenth; Sanford ore, four-sixteenths. The four-sixteenths of Sanford ore was continued until June 26. Up to and including June 18 there was nothing out of the ordinary in the furnace operations. The slags were somewhat more fluid than non-titaniferous slags, but the appearance of the cold slag was not as dense as in the previous run. The blast pressure was normal except on June 16 and 17, when the furnace tightened considerably, and then dropped back to average pressure. It was noted that the furnace was gradually falling off in the number of charges taken in proportion to the air blown. The stock at the tuyeres began to indicate "dirty hearth" conditions, and the cinder began to hang at the tuyeres persistently. The cinder refused again to flow at casting time without excessive pricking. On several occasions no cinder followed the iron although it showed plainly

at the tuyeres. After casting, even when a normal flow of cinder was had at the iron notch, cinder would show at the tuyeres in from 45 minutes to one hour. On opening the cinder notch it refused to flow. This cinder was hot and when it reached the cinder notch flowed fluid and normal. With the blast off; cinder at the tuyeres seemed to be boiling up from the bottom. I assume that at this time the bubbling was caused by the reduction of titanic acid by direct reduction by carbon in the hearth of the furnace, the reaction producing CO and causing a boiling effect which prevented the settlement of the cinder. The air blown was reduced and dolomite increased to 50 per cent. and, subsequently, on July 6, to 75 per cent. Various acidities of cinder were tried, but none of them seemed to produce the desired effect.

On June 25 the titaniferous ore was removed from the furnace in order to see whether it was the cause of the trouble. Immediately on the change reaching the tuyeres, the cinder settled from them. At the cast following there was a full flow of cinder from the iron notch. The stock passing the tuyeres continued very small and the cinder notch showed the continued "dirty hearth" conditions.

Titaniferous ore was replaced in the mixture on June 28 and on July 2 reduced to three-sixteenths. The same conditions that had existed with four-sixteenths continued. Mr. Shook insisted during this period that it would be desirable to increase the amount of wind. An air leak was repaired and the air increased on July 18 and at the same time longer tuyeres were introduced. The effect was almost instantaneous; from then throughout the remainder of the run the cinder settled from the tuyeres as freely as could be desired. The indications are that, owing to slow driving, the titaniferous slag reached the tuyeres in a viscous state. On increasing the wind, melting took place higher in the furnace and the cinder reached the tuyeres completely melted. The "dirty hearth" conditions also caused, as they always do, a throwing of some iron into the cinder. The amount of iron seemed to be very small, but was, however, sufficient to cause the cutting of cinder notches more often than had been our

regular experience. At times it seemed as if the cutting was caused by the slag itself, no iron being found in the cinder runner or in the ladle. During this period of cutting cinder notches the iron was being tapped from the iron notch at the lowest possible point. After July 12 it became necessary to use a supply of stock coke which had been weathered for almost two years. Previous to its use the furnace had been settling regularly with, for it, no abnormal pressure variations. After its use with the exception of a few days, the pressure ran up and the furnace hung and slipped until July 25 when the stock coke was removed, after which it gradually settled back to normal working at the end of the run.

On July 12 iron showed at the cinder notch, resulting in a breast being cut. Titaniferous ore was removed for 24 hours and it was again noted that immediately when the non-titaniferous mixture reached the tuyeres the cinder flowed more freely from the iron notch. It was, however, still necessary to prick the notch in order to start the cinder. The cinder from the cinder notch resumed a normal non-titaniferous appearance and was less fluid.

Fluidity tests were made throughout the whole run by pouring a ladle full of cinder dipped from the cinder runner into a runner made by pressing a 2½ inch pipe into dried coke dust, the fall of the coke dust runner being one inch in 2.5 feet. When using 25 per cent. dolomite the titaniferous cinder flowed in this runner at an average of one and one-half times, with 50 per cent. dolomite twice, and with 75 per cent dolomite two and one-half to three times the distance which normal non-titaniferous cinders, having the same apparent heat and made from half dolomite and half calcite, flow.

On July 16, the titaniferous ore was increased to one-fourth with no apparent change in the working of the furnace, and on July 19 to five-sixteenths. The increase to five-sixteenths rendered the slag stonier and denser than it had been before. The cinder notch which generally required drilling on the first flush after the cast drilled much harder, the titaniferous slag being sufficiently hard to rapidly dull drills. It showed slightly less fluidity than when using smaller

amounts, but when poured into the coke dust runner still flowed almost twice as far as non-titaniferous slag.

The sulphur in the iron which had been irregular throughout July dropped off with the increase in titaniferous ore. This drop, however, was coincident with a rise in silicon. At the same time it seemed that there was a slight return, during over 48 hours, to the tendency for the slag to hang at the tuyeres. Tuyeres No. 10 and No. 11 were cut twice during this period.

From the time of the removal of the titaniferous ore on July 29 to the end of the blast, practically all of the iron made was high in sulphur.

During February, no iron was made containing sulphur in excess of .05; during June, but one cast; during July, the sulphur content of the iron was quite variable, at times very low and at others rather high. The increase of dolomite in the mixture increased the tendency to high sulphur, it also made the slag very much denser and heavier than when using a larger percentage of calcite. The irregularities in the furnace working, due to the use of stock coke during the latter half of July, were, however, the principal cause of the high sulphur. The low sulphur content on July 10–14 were probably due to the removal of fero-manganese cinder during this period. It may seem strange, but it has been the experience at Port Henry that the use of manganese in any form, with all magnetic ores in the mixture, has invariably had a tendency to cause the production of iron of higher sulphur than when no manganese is used in the mixture.

The analysis of slag from the iron notch, when the flow was very slow and persistent pricking was necessary to get it started, did not vary greatly from that of the cinder from the cinder notch.

Samples taken on June 26 were:

	Cinder Notch	Iron Notch
Silica	30.80	32.50
Alumina	14.45	16.24
Titanic acid	5.81	4.01
Lime	40.02	37.80
Magnesia	6.88	7.41

Full analyses of slag made during the run with the various proportions of titaniferous ore and calcite and dolomite were as follows:

	June 7	June 14	June 21	July 5	July 6	July 12	July 24
Silica	29.00	30.80	27.80	32.40	32.90	31.10	29.80
Alumina	9.90	10.59	14.17	13.84	11.56	10.98	11.82
Iron Oxide					1.00	.76	1.34
Titanic acid	2.96	5.81	15.57	6.60	4.54	4.38	9.02
Lime	49.57	43.51	41.63	34.93	38.20	36.50	32.04
Magnesia	5.11	7.70	8.03	9.08	8.69	13.85	10.33
Sulphur	1.75	1.80	1.80	1.90	1.80	2.20	1.60
Vanadium oxide	.....	.....	.....	.....	.....	.....	.06
Chromium oxide	.....	.....	.....	.....	.....	.....	.014

Determinations of ferrous oxide in the cinder were made over a portion of the run, they were as follows:

July 6,	1.00	July 12,	1.76	July 20,	1.02	July 26,	.79
July 7,	1.51	July 13,	.50	July 21,	2.21	July 27,	1.58
July 8,	1.51	July 14,	1.58	July 22,	1.27	July 28,	.89
July 9,	1.26	July 15,	.76	July 23,	1.51	July 29,	1.24
July 10,	.97	July 17,	1.00	July 24,	1.34	July 30,	1.91
July 11,	1.51	July 18,	1.26	July 25,	3.02		

During June and July there was no return of any indications of the excessive cutting action of the titaniferous slag. Owing to the sticky condition of the iron notch, it was at times impossible to make proper stops so that the notch was shorter than was liked. Only one cinder break-out occurred. This was on June 17 through the hole in the jacket over the notch where the break-out had occurred during the February run. The iron broke out by the side of the notch on July 16, cutting one of the hearth plates. No special damage was done and no further break-outs occurred, although from this time to the end of the run the notch worked persistently thin. On account of the notch condition, No. 1 and No. 12 tuyeres were blanked over the full period.

Condition of Furnace after Blowing Out.

The furnace was turned over to the Northern Iron Company at 6 A. M. on August 1 and blown out at 10 A. M. on August 3. Its lines at the beginning and end of the run are shown in the accompanying diagram. The full white lines show the amount of cutting of brick, the broken lines show

the line of carbon replacement and the various strata of material found in the hearth. It will be noted that the furnace lines are very uniform, with the exception of a thickening of the carbon coating immediately over No. 1 and No. 12 tuyeres which, as stated before, were blanked during June and July. The thickness of the carbon formation was the same as it had been heretofore on blowing out the old furnace (which had been of the same construction) with the exception that heretofore the top five feet of the thin-wall section were always entirely bare of carbon coating and brick.

The formation in the hearth was abnormal in that the usual salamander of graphite and iron was largely missing. The brick work was replaced by the circular layer, marked "A" in the diagram, extending entirely around the furnace. This layer was made up of cinder, fine carbon and coke at the tuyere circle. The coke gradually disappeared toward the bottom, being replaced by cinder and graphite with some iron. Layer "B" was very similar to layer "A" but showed a distinct parting from it. Layer "C" seemed to be cinder which had not drained on the last cast. Its composition, however, indicates that it was in the furnace previous to the taking off of the titaniferous ore. Layer "D" was identical with layer "C," except that its lower 6 inches had a more metallic appearance when examined under a glass. At a point 17 feet above the tuyere circle there was a ring of coke, 6 to 10 inches in thickness horizontally and 10 to 12 inches vertically, attached to the carbon coating. This material, with the exception of one piece about 5 feet long, which seemed to have been tightly attached, fell and broke into coke and dust. Two feet below the bottom of this ring, 14 feet above the tuyere level, seemed to be the point to which the furnace was blown. From this point to the tuyeres, coke and cinder remained on the walls. This coating ranged from 6 to 12 inches in thickness. On its removal a smooth wall was shown behind it, except immediately above No. 1 and No. 2 tuyeres, where it seemed to have been attached to the carbon coating. The indications are that the furnace was free from any extensive scaffold when blown out, the

material remaining in it having become sticky after the blast was taken off. None of the coke formations were solid or showed much binding material. The material in the hearth shovelled to one foot below the cinder notch and was readily picked as far as the top of layer "C." Layer "A" showed in some places a light colored crystalline cinder which acted as a binder for the pieces of coke and carbonaceous matter. This white material only occurred through a two-foot section below the cinder notch.

The analyses of the various layers are as follows:

	Layer "A" Binding Material	Layer "A" Non-Magnetic	Layer "B" Non-Magnetic
Silica	35.74	26.54	28.24
Titanic oxide	1.04	18.26	8.14
Alumina	10.32	6.00	10.36
Iron oxide	1.27	8.93	8.12
Manganese oxide	.10	.14	.50
Lime	36.78	27.16	27.90
Magnesia	12.21	9.39	5.74
Sulphur	1.95	1.68	.90
Combined carbon	.00	1.45	.51
Graphitic carbon	.40	3.90	11.78
	99.81	103.45	102.19

The samples were separated as completely as possible by the magnet, but the so-called non-magnetic material was still slightly magnetic. The magnetic portion of layer "B" contained 0.66 per cent. titanium.

	Calculated as	Layer "C"	Layer "D"
Silica	SiO_2	9.34	8.86
Alumina	Al_2O_3	2.86	1.10
Lime	CaO	6.96	6.70
Magnesia	MgO	1.91	2.00
Titanium	Ti	42.50	44.60
Iron	Fe	20.94	18.62
Manganese	Mn	.15	.12
Sulphur	S	1.37	1.31
Combined carbon	C	4.68	5.25
Graphitic carbon	C	1.14	.77
Oxygen, Nitrogen by difference	O, N	8.15	10.67
		100.00	100.00

Magnetic separation of these samples was impossible. Qualitative tests showed the presence of considerable nitrogen.

The melting points of the materials analyzed were determined by the FitzGerald Laboratories, Niagara Falls, N. Y., as follows:

Binding Material	1390° C.
Layer "A"	1370° C.
Layer "B"	1450° C.
Layer "C"	1300° C.
Layer "D"	1410° C.

These determinations were made in a slightly oxidizing atmosphere. A second determination was made of layers "C" and "D." The initial melting points of the samples in hydrogen were the same as above reported. At 1500° C. and 1550° C. the layers "C" and "D" were melted to a pasty but non-fluid condition.

The melting points of different samples of the above materials were determined by Joseph F. Cullum, of the Bureau of Mines. These tests were made in an atmosphere of CO and were as follows: the binding material of layer "A" melted at 1227° C., layer "A" at 1209° C., layer "D" softened at 1330° C. and melted partially but not into a fluid globule at 1427° C.

Samples of material from layers "C" and "D" were submitted to Professor Bacon, of the Rensselaer Polytechnic Institute, Troy, N. Y., with the request that he determine the melting point of these materials in vacuum, and also the temperature at which they become fluid, if he could render them fluid. He reports that the sample of material from layer "C" was heated to 2000° C. without melting; it lost 39 per cent. in weight. The sample from layer "D" melted at 1240° C., but did not become fluid until carried to 1784° C. It lost 7 per cent. in weight. It has been noted that none of the melting points reported, with the exception of those determined in vacuum, exceed the observed temperature of cinder flowing from the runner into the cinder ladle, and that the materials found in layers "C" and "D" did not melt at this temperature to a fluid state. The specific gravity of the substance has not been determined, but it is apparently much below that of cast iron. It is evident that this substance exists in the hearth of the furnace in a viscous

state and more than likely in a layer floating on the iron and between it and the cinder. This supposition at least explains why iron was always readily tapped from the extreme bottom of the hearth, from which point it flowed freely, and why, after the iron had flowed from the furnace, the cinder refused to follow without excessive pricking. A viscous condition of this substance also explains the apparent "dirty hearth" conditions. If it floated on top of the iron in the hearth, it would tend to prevent the settling of melted iron to the bottom of the hearth and cause iron, which was held in the higher levels, to pass out through the cinder notch. It had been previously noted that on a non-titaniferous mixture reaching the hearth of the furnace, almost instantly conditions became nearly normal. Pricking to get a cinder flow at the iron notch was necessary for from two to four casts, after which a full free flow came. The material, therefore, seems to be extremely easily fluxed, or if not fluxed very easily washed from the hearth, and a further study of it will, I think, unquestionably result in a simple method of preventing or removing it without the removal of the titaniferous ore from the mixture.

A sample of the mixture of iron, cinder and graphite found in the hearth of a furnace using non-titaniferous ores was submitted to Professor Bacon with the request that he determine its melting point under the same conditions under which he determined the melting point of the titaniferous compounds. He reports that the sample showed a pronounced bubbling at 1793° C. when the more volatile constituents passed off. The temperature was carried to 1923° C. without melting. There was a loss in weight of 37 per cent. The residue must contain some calcium carbide as the odor is quite pronounced.

A very careful search was made of all the material left in the hearth for the much feared copper colored crystals of cyanonitride of titanium. One of the foremen reported having seen a few yellow crystals in the layer of semi-fused brick in the extreme bottom of the hearth, but as he did not retain the sample its presence is doubtful.

An account of experimental work in the blast furnace is

necessarily an account of conditions which are other than normal and of the troubles and difficulties met and overcome together with those which have not been overcome. The troubles and difficulties met in the experimental run which I have just outlined were as nothing compared with those which were met during the first three months of the operation of the Port Henry furnace on all magnetic ores.

An abstract of the weekly results while using titaniferous ore is given on Table 4.

Results of the furnace operations, by months, for the year 1913 and for the period it was operated by the MacIntyre Iron Company during 1914 are shown on Table 5. For commercial reasons all pig iron produced at this furnace which contains more than .05 per cent. sulphur is returned to the furnace and remelted. This accounts for the large amount of remelted iron.

Conclusions Reached from the Experiments.

In a general way, the conclusions which I am able to draw from the experimental run, short as it was, are:

Titaniferous concentrates are reduced in the furnace with no greater and probably with less expenditure of heat, and consequently of fuel, than non-titaniferous magnetites, and as a greater proportion of their oxygen is removed by the action of CO than is the case with non-titaniferous magnetites, a lower fuel consumption for the reduction of the iron may be expected. The slower driving of the furnace for the same wind blown seems to be explicable only on the assumption that more carbon was burned in the hearth and less in the upper portions of the furnace. With proper concentration, Sanford ore should be produced containing iron from 58 to 60 per cent., and from 9 to 10 per cent. TiO_2. The weight of slag produced per ton of iron from an ore of this composition will be slightly greater than that produced from the average magnetic concentrate containing 62 to 63 per cent. of iron. This additional slag production will about counterbalance the reduced fuel consumption necessary for the reduction of their iron contents. The slags produced

will be of much greater fluidity than those produced when TiO_2 is not present. The operation of the furnace above the tuyere level will be more uniform and there will be less tendency to hang and slip. The iron produced will contain less sulphur. Its silicon contents will be lower by an amount equal to one-half of the titanium content. With titanic acid in the slag in excess of 6 per cent. the production of high silicon iron, that is iron containing over 2 per cent. silicon, will be more difficult. The titaniferous ore being low in silica is not adapted for the production of high silicon iron. At least until further investigation is made, there is likely to be a tendency to periodical "dirty hearth" conditions in the working of the ore, but they are readily stopped by the removal of titaniferous ore from the mixture for short periods.

Chart I shows graphically the furnace operations and the analyses of the cinder and iron produced.

Table 6 gives physical tests of a series of test bars which were cast from iron as it flowed from the furnace. These bars were made in accordance with the standard specifications for gray iron castings of the American Society for Testing Materials, with the exception that the moulds were not dried. The bars were broken in part by the Titanium Alloy Manufacturing Co., Niagara Falls, N. Y., and in part by the United States Bureau of Standards. It will be noted that the titaniferous iron averages stronger than non-titaniferous iron of the same silicon content.

Samples of pig iron made from all Lake ores by a furnace in the Buffalo District were obtained, test bars, shrinkage and chill tests were made from them and from titaniferous iron of the same silicon content. These are shown in Table 7 together with the analyses of the casting and of the pig iron before melting. The pig was melted alone, with 50 per cent., and in the case of titaniferous iron with 70 per cent., of stove plate scrap. The sample of non-titaniferous iron was not of sufficient quantity to make tests from it with 70 per cent. of stove plate scrap. The strength of the bars made from the titaniferous pig was higher than that from the non-titaniferous pig, with one exception. The shrinkage of both irons was practically the same. The chill from the titanifer-

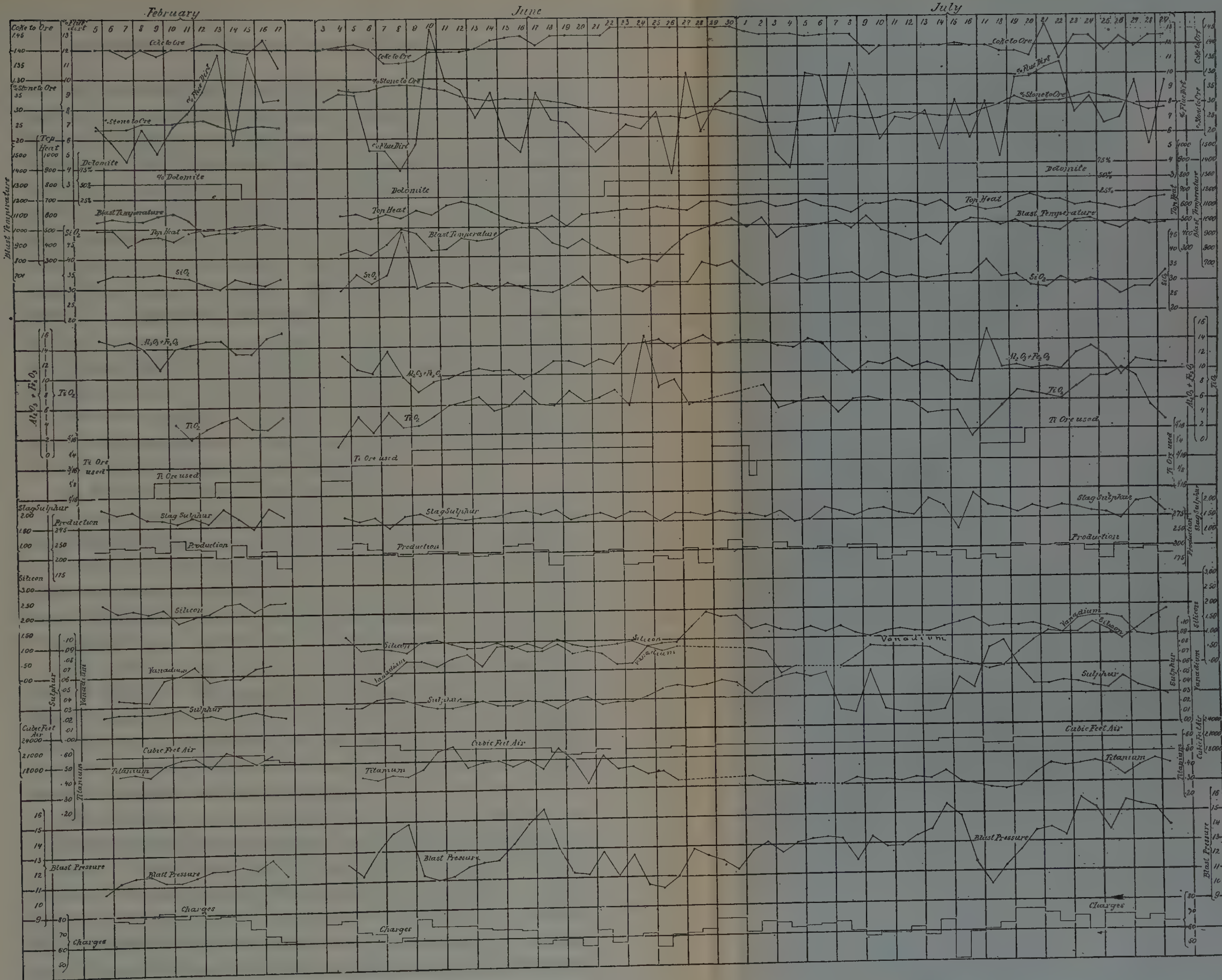


CHART I. FURNACE OPERATIONS AND ANALYSIS OF CINDER AND IRON PRODUCED

ous iron was distinctly less than that from the non-titaniferous iron. It carried 70 per cent. scrap with no greater chill than the Buffalo iron had with 50 per cent. The loss of titanium in remelting was quite apparent, although it was less than was expected. The loss of vanadium was considerably less. It will be further noted that the stove plate scrap used contained some vanadium; qualitative examination of it also shows that it contained titanium; quantitative examinations were not made. The irons for these tests were melted in a graphite crucible in a coke furnace somewhat similar to a steel melting furnace. The stove plate scrap used was broken into very small pieces and thoroughly mixed in the pile, so that it was practically uniform in composition.

Photo-micrographs of some of the castings are shown; also of two samples of titaniferous pig iron, which show the characteristic cubical titanium crystals.

At this point it may be interesting to note that all pig iron made from Connellsville coke, which I have examined, contained appreciable amounts of titanium and vanadium.

Table 8 gives analyses of all Lake ore iron. Table 9 gives analyses of foundry irons made at Port Henry, N. Y., from Mineville ores and of low phosphorus irons made at Standish, N. Y., from Lyon Mountain ore.

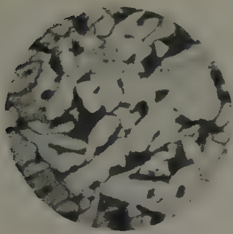
Reference to the titanium contents of iron produced indicates that the titanium contents of the iron is not directly proportionate to the titanium in the charge. It does not directly follow the silicon or the sulphur. The vanadium content of the iron is more nearly proportionate to the amount charged, but not entirely so.

The foundry iron produced in February was shipped to customers with the request that they report the results from its use. In most cases the customers failed to respond to our request. In no case did they report unfavorably. Where reports were made, they were either that the iron increased the strength of their mixture without hardening it, or that they did not notice any change in the quality of their castings. One customer reported that the use of 20 per cent. of titaniferous iron in his mixture gave him the strongest test bar he had ever broken, and that the increased strength over

his average test bars was 23 per cent. One sample lot of the iron was puddled, the report on it being that no difference from ordinary iron was noted either in its working in the puddle furnace or in the bars produced. Two customers using the iron for malleable castings advise that preliminary tests show that the iron is not different from similar malleable irons, either in its working or in the quality of the finished castings.

Table 10 gives the results obtained from the use of this iron in the manufacture of basic open hearth steel and photomicrographs of the steel produced.

Table 11 gives the result of a test made to determine the oxidation of the metalloids when titaniferous pig iron was melted in a graphite crucible with iron ore additions. (Applause.)



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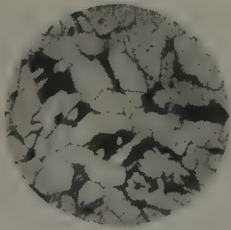

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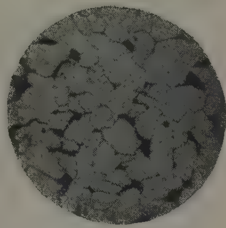

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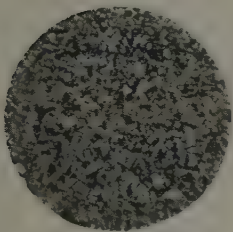

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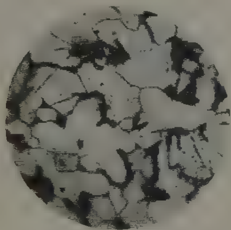
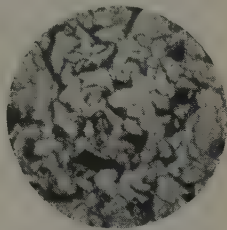
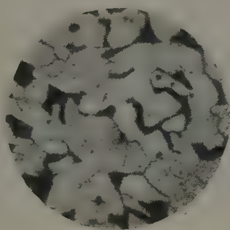


Heat No. 2135.

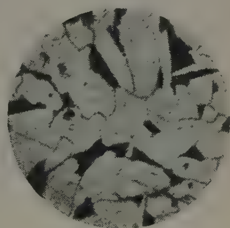


Heat No. 2138.

Heat No. 2139.

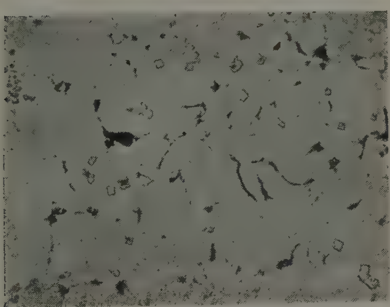


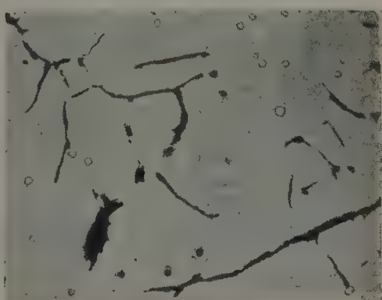
Heat No. 2140.



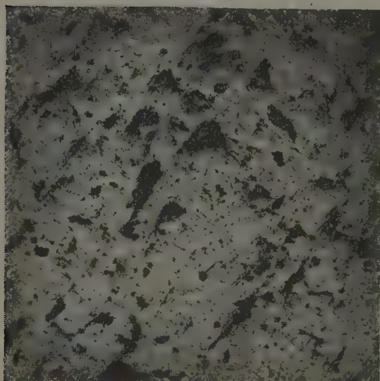
Heat No. 4342.

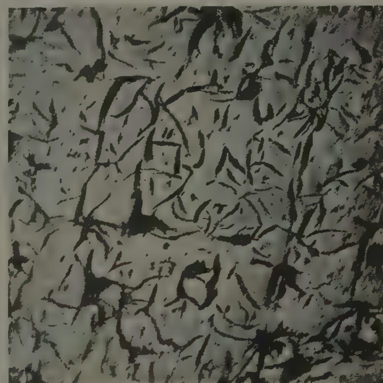
Photomicrographs of open hearth steel made from titaniferous pig iron. The heat numbers refer to data given in Table 10.

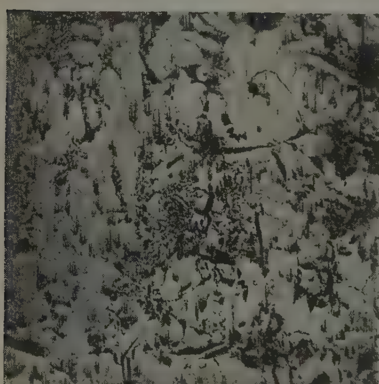




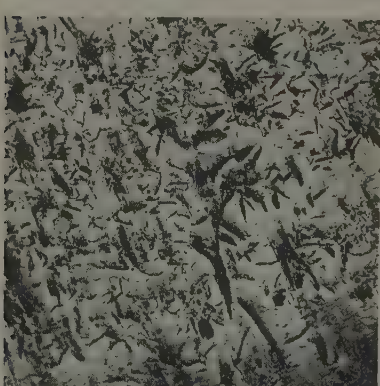
Photomicrographs of titaniferous pig iron (×400).

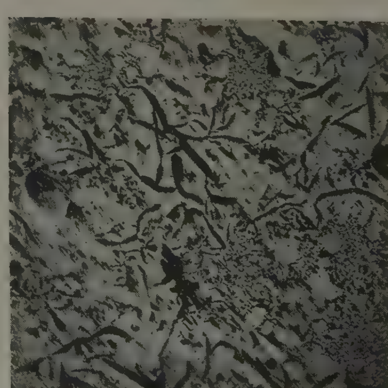

T-1-1 ×100


B-1-1 ×100


T-2-1 ×100


B-2-1 ×100

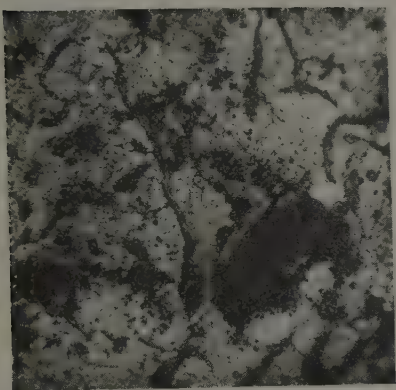

T-3-1 ×100


B-3-1 ×100

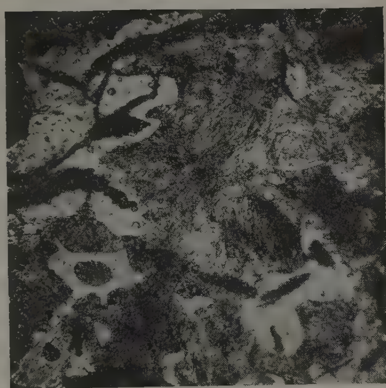
Photomicrographs of titaniferous and non-titaniferous pig iron (unetched). The index numbers refer to data given in table.

T-4-1 ×100

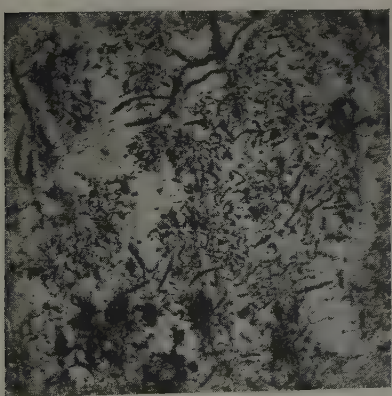
B-4-1 ×100



T-4-1 ×430



B-4-1 ×430



T-4-2 ×100

B-4-2 ×100

Photomicrographs of titaniferous and non-titaniferous pig iron (unetched). The index numbers refer to data given in table.

TABLE I.—ANALYSES, SPECIFIC GRAVITY, MELTING POINT AND FLUIDITY OF TITANIFEROUS SLAGS.

Number of Sample	1	2	3	4	4A	4B	4C	4D	5	6	6A	6B	7 (2)	7 (3)	9	12
Calculated Per Cent. of TiO_2	5	9	12	16	16	16	16	16	18	21	21	21	0	0	Blast Fce. Slag	..
Per Cent. of Acidity ($SiO_2+Al_2O_3+\frac{3}{4}TiO_2$)	48.10	49.65	48.91	45.52	47.51	51.67	53.51	49.15	57.97	49.40	48.31	All Dolomite	42.22	42.19	42.78	46.18
Silica	29.52	27.02	25.26	20.22	22.86	25.38	27.74	24.94	19.92	16.80	20.90	20.20	37.46	30.46	32.82	33.44
Titanic oxide	5.02	10.52	10.40	13.16	17.37	16.36	15.98	16.52	21.54	22.54	19.34	21.65	.....	.82	1.48	.....
Alumina	15.80	14.74	15.84	15.43	11.62	14.00	14.00	11.82	15.90	15.67	12.91	14.40	4.76	11.02	8.85	12.74
Iron oxide (FeO)	.56	.43	.71	1.73	1.29	.43	.14	.86	1.72	.56	1.57	.....	1.15	1.15	.71	.86
Lime	36.43	33.73	34.76	38.19	33.10	39.03	25.28	32.86	30.80	31.42	42.08	23.85	41.53	45.36	41.23	39.03
Magnesia	9.96	9.43	10.43	10.28	11.29	2.26	14.44	9.50	9.17	9.82	2.15	16.92	12.82	8.34	10.94	9.28
Calcium sulphide	1.95	2.97	2.47	1.82	1.75	1.68	1.77	2.14	.29	1.31	1.34	1.35	1.27	1.65	2.23	3.96
Alkalies	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.56	.....	.....	.....	.....	.....
Carbon	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.35	.....	.....	.....	.....	.....
Manganese oxide	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.20	.....
Total	99.24	98.84	99.87	100.83	99.28	99.14	99.35	98.64	99.34	98.16	101.20	98.37	98.99	98.80	98.46	99.31
Specific Gravity	2.971	3.112	3.123	3.263	3.180	3.068	3.154	3.206	3.378	3.190	3.276	.....	3.073	3.104	3.014	.....
Melting point, C°	1334	1285	1338	1328	1374	1373	1286	....	1406	1450	1434	1355	1355	1447	1321	1391
Fluidity * Length of flow (titaniferous)	5′ 5″	5′ 1″	3′ 9″	0′ 9″	5′ 1″	2′ 2″	4′ 6″	....	4′ 5″	3′ 2″	1′ 6″	3′ 0″	....	....	....	....
Length of flow (non-titaniferous)	4′ 5″	3′ 11″	3′ 1″	2′ 11″	....	....	....	....	5′ 2″	5′ 1½″	....	....	....	....	4′ 9″	3′ 6″

* The fall in the runner was 1″ in 2′ 6″, except in case of samples 5 and 6, where it was 1″ in 1′.

NOTE—Sample *4a* fused with iron gave an analysis of 2.35 per cent. calcium sulphide. Sample 10, remelted furnace slag, using one-half calcite and one-half dolomite, had a melting point of 1363° C.; using one-fourth calcite and three-fourths dolomite (sample 11), a melting point of 1310° C.

TABLE II.

ANALYSES OF PIG IRON, FEBRUARY RUN.

No. of Cast	Silicon	Sulphur	Phos-phorus	Manga-nese	Titani-um	Vana-dium	Graph-itic Carbon (Chilled	Com-bined Carbon Sample)
215	1.80	.020	.729	.47	.38	.036	..	..
216	1.90	.022	.729	.38	.456	.035	..	..
218	2.70	.019	.729	.42	.456	.038	..	..
219	2.50	.019	.666	.46	.50	..	3.38	.31
220	1.80	.021	.666	.45	.441	.038	3.60	.33
221	2.10	.020	.666	.45	.418	.035	..	..
222	2.80	.018	.666	.53	.459	.030	3.45	.31
223	2.55	.023	.666	.41	.444	.034	3.16	.40
224	1.70	.036	.666	.39	.340	.033	3.07	.52
225	1.60	.030	.664	.42	.310	.030	3.27	.57
226	1.55	.024	.664	.46	.36	.033	3.33	.56
227	2.10	.023	.664	.45	.45	.030	..	..
228	1.75	.027	.664	.46	.44	.037	..	..
229	1.75	.027	.664	.44	.38	.037	..	..
230	2.00	.028	.664	.48	.432	.0376	..	..
231	2.10	.020	.652	.48	.47	.042	..	..
232	2.03	.020	.652	.45	.506	.0496	..	..
233	1.95	.019	.652	.50	.556	.0594	3.23	.47
234	1.85	.017	.652	.49	.547	.064	3.36	.62
235	1.97	.019	.652	.47	.488	.064	3.37	.46
236	2.00	.019	.652	.49	.494	.058	3.42	.41
237	2.00	.017	.63	.53	.575	.065	..	..
238	2.05	.020	.63	.51	.560	.058	..	..
239	1.75	.021	.63	.53	.50	.062	3.05	.65
240	2.00	.020	.63	.54	.559	.056	..	..
241	2.10	.019	.63	.54	.497	.062	..	..
242	2.45	.020	.63	.57	.579	.059	3.09	.50
243	2.55	.015	.65	.55	.595	.067	..	..
244	3.10	.014	.65	.57	.595	.075	..	..
245	2.75	.015	.65	.44	.555	.065	..	..
246	2.00	.018	.65	.39	.602	.065	..	..
247	1.95	.017	.65	.41	.496	.069	3.33	.55
248	1.95	.023	.65	.40	.50	.064	3.18	.62
249	2.20	.017	.61	.49	.523	.055	..	..
250	2.43	.019	.61	.49	.469	.058	3.37	.45
251	2.40	.018	.61	.47	.479	.049	..	..
252	2.95	.019	.61	.51	.503	.052	3.45	.29
253	2.40	.024	.61	.48	.479	.053	3.20	.31
254	2.35	.024	.61	.48	.493	.056	3.25	.33

Casts 215 to 231 inclusive, one-sixteenth of Sanford ore was used.
Casts 232 to 254 inclusive, two-sixteenths of Sanford ore were used.
Graphitic carbon weighed direct, combined carbon by color.
Carbon not given when the pig iron was shipped before the determination was begun.

A sand cast sample of Cast 243 gave graphitic carbon 3.62, combined carbon .20; of Cast 244, graphitic carbon 3.10, combined carbon .135.

TABLE III.—SLAG AND METAL BLACK BODY TEMPERATURES.

Date	Time	Cast No.	Taken On	Temperature Degrees F.
Feb. 7	1:00 P.M.	215	2nd flush	2642
	2:30 P.M.	215	iron	2372
	2:30 P.M.	215	cinder	2638
	5:15 P.M.	216	1st flush	2561
	5:30 P.M.	216	2nd flush	2609
	6:05 P.M.	216	3rd flush	2690
	6:30 P.M.	216	iron	2417
	6:30 P.M.	216	cinder	2638
8	10:20 A.M.	220	flush	2705
	10:35 A.M.	220	iron	2372
	10:35 A.M.	220	cinder	2638
	6:15 P.M.	222	1st flush	2674
9	9:30 A.M.	226	1st flush	2633
	2:30 P.M.	227	1st flush	2620*
	5:15 P.M.	228	1st flush	2804*
	6:05 P.M.	228	2nd flush	2770*
	6:20 P.M.	228	3rd flush	2730*
	6:30 P.M.	228	iron	2463*
10	2:00 P.M.	233	3rd flush	2550
	2:30 P.M.	233	iron	2360
	2:30 P.M.	233	cinder	2633
	5:05 P.M.	234	1st flush	2718
	9:45 P.M.	235	2nd flush	2674
	10:30 P.M.	235	iron	2372
	10:30 P.M.	235	cinder	2654
11	10:30 A.M.	238	iron	2460
	2:30 P.M.	239	iron	2460
	2:30 P.M.	239	cinder	2640
12	10:30 A.M.	244	iron	2350
	6:30 P.M.	246	iron	2486
	10:30 P.M.	247	flush	2800
	10:30 P.M.	247	iron	2508
13	10:30 A.M.	250	flush	2761
	10:45 A.M.	250	iron	2550†
	6:00 P.M.	252	cinder	2800
	11:15 P.M.	253	cinder	2760
14	10:00 P.M.	259	flush	2650
15	6:00 P.M.	264	flush	2750
16	10:30 P.M.	...	iron	2550
17	5:30 P.M.	...	flush	2710
19	10:55 A.M.	281	iron	2280
	10:55 A.M.	281	cinder	2590
20	2:30 P.M.	287	flush	2690
21	10:30 A.M.	292	cinder	2650
	10:30 A.M.	292	iron	2500
May 26	10:15 A.M.	...	flush	2460
27	2:00 P.M.	...	flush	2530
28	10:00 A.M.	...	flush	2700

* Taken with a Wanner instrument, all others taken with a Holburn-Kurlbaum instrument.

† Temperature taken one foot from tap.

TABLE III.—SLAG AND METAL BLACK BODY TEMPERATURES—Continued.

Date	Time	Cast No.	Taken On	Temperature Degrees F.
June 3	10:15 A.M.	723	flush	2700
4	9:00 A.M.	729	flush	2690
	10:00 A.M.	729	flush	2690
5	9:15 A.M.	735	flush	2710
6	2:00 P.M.	742	flush	2650
	10:00 P.M.	744	flush	2620
7	9:00 A.M.	747	2nd flush	2600
8	2:30 P.M.	754	2nd flush	2680
	5:00 P.M.	755	1st flush	2580
	5:00 P.M.	755	2nd flush	2562
9	9:00 A.M.	759	2nd flush	2642
	2:00 P.M.	760	1st flush	2610
	4:30 P.M.	761	1st flush	2620
	5:00 P.M.	761	2nd flush	2640
10	9:30 A.M.	765	2nd flush	2660
	1:30 P.M.	766	2nd flush	2696
11	1:00 P.M.	772	2nd flush	2687
	2:00 P.M.	772	3rd flush	2698
	4:40 P.M.	773	1st flush	2728
12	8:30 A.M.	777	1st flush	2777
	9:15 A.M.	777	2nd flush	2822
	4:30 P.M.	779	1st flush	2804
13	9:00 A.M.	783	2nd flush	2867
	1:00 P.M.	784	2nd flush	2826
	4:00 P.M.	785	1st flush	2856
14	5:50 A.M.	788	flush	2720
	9:15 A.M.	789	flush	2840
	1:30 P.M.	790	flush	2885
	4:25 P.M.	791	flush	2810
15	9:45 A.M.	...	flush	2796
	4:00 P.M.	...	flush	2720
	5:00 P.M.	...	flush	2720
16	5:00 P.M.	...	flush	2768
	5:00 P.M.	...	flush	2790
	10:00 P.M.	...	iron	2675
17	10:00 A.M.	...	flush	2850
	1:00 P.M.	...	flush	2780
	4:00 P.M.	...	flush	2805
	9:40 P.M.	...	flush	2805
18	1:45 P.M.	...	flush	2850
	4:15 P.M.	...	flush	2675‡
	5:00 P.M.	...	flush	2795
19	2:00 P.M.	...	flush	2790
	4:00 P.M.	...	flush	2710
	4:30 P.M.	...	flush	2770
	5:00 P.M.	...	flush	2770*
20	4:00 P.M.	...	flush	2695
	4:15 P.M.	...	flush	2720

* Taken with a Wanner instrument, all others taken with a Holburn-Kurlbaum instrument.

‡ Running slowly.

TABLE III.—Slag and Metal Black Body Temperatures—Continued.

Date	Time	Cast No.	Taken On	Temperature Degrees F.
June 21	10:00 A.M.	...	flush	2730*
	5:00 P.M.	...	flush	2805
	9:15 P.M.	...	flush	2860
22	10:30 P.M.	...	flush	2870
23	4:50 P.M.	...	flush	2720
24	12:45 A.M.	...	flush	2810
	4:30 A.M.	...	flush	2795
	4:00 P.M.	...	flush	2780
25	9:00 A.M.	...	flush	2770
26	10:00 A.M.	...	flush	2770
27	9:40 A.M.	...	flush	2750
	4:30 P.M.	...	flush	2630
	4:30 P.M.	...	flush	2670
	4:30 P.M.	...	flush	2710
28	5:00 P.M.	...	flush	2760
29	8:45 A.M.	...	flush	2750
	1:30 P.M.	...	flush	2740*
	2:00 P.M.	...	flush	2760
30	9:30 A.M.	...	flush	2770*
July 4	11:30 A.M.	...	flush	2770

* Taken with a Wanner instrument, all others taken with a Holburn-Kurlbaum instrument.

TABLE IV.—Average Weekly Results of Furnace Operation While Using Titaniferous Ore.

	Iron Yield, Per Cent. Ore	Coke, Lbs. Per Ton of Iron	Limestone, Lbs. Per Ton of Iron	Limestone, Per Cent. Ore Charged	Blast, Cu. Ft. Per Pound Full	Production, Gross Tons
Foundry:						
Feb. 7–14	60.15	2537	858	23.00	51.1	1544
Malleable:						
June 1– 8	56.78	2260	1156	29.30	62.5	1511
June 8–15	59.87	2403	1137	30.40	60.6	1465
June 15–22	55.55	2255	987	24.40	63.0	1369
June 22–30	57.52	2365	942	24.20	63.2	1688
July 1– 8	59.16	2246	810	21.30	61.8	1466
July 8–15	57.34	2354	865	22.10	66.3	1287
July 15–21	63.20	2453	1017	28.70	57.4	1346
July 21–31*	66.29	2272	892	26.40	62.0	1903

* Stock in furnace was deducted from coke, ore and stone charged.

TABLE V.—AVERAGE MONTHLY RESULTS OF FURNACE OPERATION, JANUARY, 1913, TO JULY, 1914.

Months	Coke Lbs.	Stone Lbs.	Marble Lbs.	Ore Lbs.	Tons of Iron Made	Tons of Iron Re-melted	Yield of Ore, Per Cent.	Lbs. of Coke Per Ton of Iron	Lbs. of Stone Per Ton of Iron	Lbs. of Ore Per Ton of Iron	Lbs. of Coke Per Lb. Ore	Lbs. Coke Per Lb. Ore, Stone and Marble	Theoretical Yield, Per Cent.	Tons Pig Lost in Flue Dust	Per Cent. Pig Lost in Flue Dust	Per Cent. of Iron Made with Silicon below 1.25	Per Cent. of Iron Made with Silicon 1.25 to 2.00	Per Cent. of Iron Made with Silicon above 2.00	Per Cent. of Iron Made with Sulphur above .05
1913																			
January	16,318,300	3,267,400	3,269,150	21,943,980	6,431	292	62.8	2,658	1,065	3,574	1.344	1.745	......	......	.....	7	17	75	13
February	12,960,800	3,139,810	3,139,810	19,035,935	5,674	413	61.9	2,463	1,194	3,618	1.469	1.953	......	......	.....	44	53	2	22
March	14,013,550	2,831,860	2,831,860	19,173,666	6,010	496	64.3	2,541	1,027	3,477	1.368	1.772	......	......	.....	8	48	41	8
April	13,164,800	2,644,610	2,644,610	19,946,520	6,112	60	67.9	2,175	874	3,296	1.515	1.917	......	......	.....	12	66	20	7
May	14,060,700	2,817,230	2,817,230	20,816,906	6,159	390	62.9	2,439	977	3,561	1.480	1.881	......	......	.....	40	37	22	10
June	13,260,000	2,724,550	3,522,870	19,850,580	3,757	481	61.1	2,518	1,184	3,666	1.497	1.968	......	......	.....	70	28	..	11
July	12,421,900	2,605,360	2,605,360	18,768,345	5,444	80	67.5	2,316	971	3,318	1.511	1.930	......	......	.....	42	54	1	1
August	11,717,100	2,272,530	2,272,530	15,846,523	4,831	263	67.1	2,575	995	3,335	1.352	1.740	......	......	.....	10	86	4	1
September	13,953,000	2,564,010	3,410,730	20,235,029	6,440	1,552	54.1	2,854	1,049	4,140	1.450	1.878	.....	......	.....	30	66	3	8
October	14,899,225	4,349,245	3,498,160	21,159,770	6,307	768	58.6	2,689	1,417	3,820	1.420	1.947	......	......	.....	42	56	..	8
November	17,179,995	2,977,120	4,282,200	17,366,870	6,539	591	76.7	2,887	963	3,669	1.449	1.821	......	......	.....	3	35	59	10
December	16,955,510	581,285	4,869,417	24,648,510	8,175	988	65.3	2,359	661	3,429	1.454	1.775	......	......	.....	5	34	60	5
Total	170,904,880	32,775,010	39,163,927	238,792,634	73,879	6,374	63.33	2,532	1,066	3,537	1.397	1.818	......	......	.....	.....	.....	.....	.....
1914																			
January	16,260,525	2,183,710	2,707,340	22,569,258	6,775	644	61.79	2,400	722	3,625	1.387	1.688	64.85	461.56	7.17	10	25	65	10
February	14,432,039	2,319,670	2,438,670	20,531,070	5,857	259	61.89	2,464	812	3,619	1.404	1.733	64.005	354.06	6.12	..	20	79	2
March	11,430,600	2,136,860	2,136,860	16,308,840	4,984	339	64.85	2,293	857	3,454	1.403	1.777	65.389	236.77	5.06	2	42	55	3
April	4,876,920	908,130	908,130	6,624,295	1,756	37	58.83	2,777	1,034	3,807	1.342	1.714	64.54	71.77	3.76	..	37	62	4
May	16,327,700	2,569,465	4,075,195	22,950,289	6,690	386	62.25	2,440	993	3,598	1.389	1.796	65.41	250.66	3.78	23	45	31	20
June	13,896,370	1,908,735	4,390,345	19,874,830	5,983	957	57.45	2,322	1,052	3,898	1.409	1.863	64.54	341.50	6.05	78	20	1	5
July	13,950,507	3,091,130	2,278,150	19,523,330	5,844	660	60.00	2,387	919	3,733	1.387	1.772	64.638	316.40	5.53	48	46	6	21
Total	91,174,661	15,117,700	18,934,690	128,381,912	37,889	3,282	61.01	2,440	912	3,676	1.389	1.763	......	......	.....	.....	.....	.....	.....

TABLE VI*a*.—Transverse Tests on Non-Titaniferous Cast Iron.

Cast No.	Nominal Diameter, inches	Breaking Load, pounds	Average Breaking Load	Ultimate Deflection, inches	Analysis			
					Si.	S.	P.	Mn.
1	1.25	2470	2454	.115	0.65	.074	.168	.30
	1.25	2439		.115	0.65	.074	.168	.30
2	1.25	3260	3260	.20	0.75	.09	.128	.31
3	1.25	2681	2582	.145	1.00	.055	.128	.45
	1.25	2484		.145	1.00	.055	.128	.45
4	1.25	2400	2281	.120	1.05	.065	.190	.43
	1.25	2163		.120	1.05	.065	.190	.43
5	1.25	3372	3347	.135	1.05	.074	.142	.37
	1.25	3323		.135	1.05	.074	.142	.37
6	1.25	2603	2685	.165	1.13	.034	.140	.46
	1.25	2768		.165	1.13	.034	.140	.46
7	1.25	2326	2420	.150	1.15	.031	.130	.49
	1.25	2514		.150	1.15	.031	.130	.49
8	1.25	2535	2453	.145	1.20	.031	.136	.51
	1.25	2372		.145	1.20	.031	.136	.51
9	1.25	2620	2620	.15	1.21	.049	.195	.50
10	1.25	3006	3002	.125	1.25	.052	.578	.37
	1.25	2998		.125	1.25	.052	.578	.37
11	1.25	3220	3220	.15	1.25	.056	.65	.37
12	1.25	3180	3022	.145	1.30	.053	.646	.40
	1.25	2864		.145	1.30	.053	.646	.40
13	1.25	3020	3020	.18	1.40	.045	.65	.39
14	1.25	2800	2800	.15	1.40	.058	.284	.45
15	1.25	3420	3420	.22	1.50	.054	.65	.36
16	1.25	2906	2885	.150	1.55	.024	.145	.49
	1.25	2864		.150	1.55	.024	.145	.49
17	1.25	3000	3207	.18	1.60	.039	.581	.46
	1.25	3415		.21	1.60	.039	.581	.46
18	1.25	3056	3095	.150	1.65	.054	.350	.49
	1.25	3134		.150	1.65	.054	.350	.49
19	1.25	2772	2918	.13	1.80	.032	.581	.46
	1.25	3065		.13	1.80	.032	.581	.46
20	1.25	2580	2790	.19	1.80	.034	.272	.49
	1.25	3000		.19	1.80	.034	.272	.49
21	1.25	2961	2878	.125	1.95	.036	.578	.42
	1.25	2796		.125	1.95	.036	.578	.42
22	1.25	3022	2965	.135	2.05	.034	.581	.44
	1.25	2908		.135	2.05	.034	.581	.44
23	1.25	3036	3025	.150	2.10	.025	.145	.57
	1.25	3015		.150	2.10	.025	.145	.57
24	1.25	2730	2730	.20	2.20	.021	.58	.48
25	1.25	2800	2850	.21	2.40	.023	.56	.50
	1.25	2900		.17	2.40	.023	.56	.50
26	1.25	3260	3260	.19	2.40	.027	.584	.50
27	1.25	3060	3060	.14	2.45	.031	.578	.49
28	1.25	2740	2740	.16	2.65	.019	.569	.46
29	1.25	2890	2765	.23	2.90	.021	.571	.52
	1.25	2640		.16	2.90	.021	.571	.52
30	1.25	2565	2565	.16	3.05	.019	.584	.55

Average breaking load Si .00–0.99%, 2857 lbs.
" " " " 1.00–1.49%, 2788 "
" " " " 1.50–1.99%, 3030 "
" " " " 2.00–2.49%, 2982 "
" " " " 2.50–2.99%, 2752 "

TABLE VI*b*.—TRANSVERSE TESTS ON TITANIFEROUS CAST IRON.

Cast No.	Nominal Diameter, Inches Width	Nominal Diameter, Inches Height	Breaking Load, Pounds	Average Breaking Load	Ultimate Deflection, Inches	Analysis Si.	Analysis S.	Analysis P.	Analysis Mn.	Analysis Ti.	Analysis V.
743	1.36	1.33	3059	3020	.095	.65	.046	.184	.41	.246	.058
743	1.31	1.30	2982			.65	.046	.184	.41	.246	.058
791	1.30	1.30	2417	2564	.135	.70	.030	.149	.39	.399	.085
791	1.28	1.30	2712			.70	.030	.149	.39	.399	.085
1039	1.28	....	3100	3050	.172	.70	.041	.120	.42	.350	.106
1039	1.28	....	3000		.180	.70	.041	.120	.42	.350	.106
795	1.28	....	2800	2730	.152	.72	.026	.148	.43	.498	.080
795	1.28	....	2660		.147	.72	.026	.148	.43	.498	.080
845	1.28	....	3680	3420	.154	.75	.030	.226	.53	.390	.085
845	1.28	....	3160		.137	.75	.030	.226	.53	.390	.085
754	1.26	1.26	3462	3543	.115	.77	.029	.152	.47	.493	.071
754	1.26	1.27	3624			.77	.029	.152	.47	.493	.071
765	1.27	1.26	2624	2624	.135	.80	.026	.148	.55	.555	.074
773	1.27	1.26	3165	3076	.135	.80	.031	.142	.56	.471	.077
773	1.27	1.26	2988			.80	.031	.142	.56	.471	.077
779	1.28	1.28	2707	2782	.150	.80	.027	.140	.54	.434	.066
779	1.28	1.26	2858			.80	.027	.140	.54	.434	.066
735	1.30	1.30	3019	2874	.150	.80	.028	.166	.47	.436	.048
735	1.29	1.28	2730			.80	.028	.166	.47	.436	.048
802	1.28	....	3000	3000	.174	.82	.027	.128	.46	.430	.082
850	1.28	....	3560	3515	.155	.85	.037	.216	.56	.417	.079
850	1.28	....	3470		.141	.85	.037	.216	.56	.417	.079
736	1.30	1.29	2741	2704	.145	.90	.027	.174	.47	.468	.048
736	1.28	1.29	2667			.90	.027	.174	.47	.468	.048
737	1.27	1.26	2883	2857	.135	.90	.040	.178	.45	.356	.048
737	1.28	1.28	2832		.159	.90	.040	.178	.45	.356	.048
939	1.28	....	3020	3040	.155	.90	.049	.192	.35	.328	.082
939	1.28	....	3060			.90	.049	.192	.35	.328	.082
742	1.28	1.27	3226	3184	.125	.94	.027	.182	.31	.410	.058
742	1.27	1.27	3142			.94	.027	.182	.31	.410	.058
852	1.28	....	3050	3050	.131	.97	.040	.216	.53	.417	.079
741	1.26	1.27	2921	3009	.140	1.00	.033	.180	.41	.426	.058
741	1.26	1.27	3097			1.00	.033	.180	.41	.426	.058
849	1.28	....	3080	3080	.128	1.00	.031	.222	.51	.417	.079
938	1.28	....	3140	3175	.130	1.00	.064	.202	.36	.328	.082
938	1.28	....	3210		.140	1.00	.064	.202	.36	.328	.082
940	1.28	....	2880	2820	.150	1.00	.063	.180	.43	.328	.082
940	1.28	....	2760		.150	1.00	.063	.180	.43	.328	.082
1016	1.28	....	3190		.146	1.00	.036	.172	.44	.410	.093
1016	1.28	....	3470	3330	.166	1.00	.036	.172	.44	.410	.093
1017	1.28	....	2780	2390	.164	1.00	.059	.150	.36	.410	.093
1017	1.28	....	3000		.156	1.00	.059	.150	.36	.410	.093
955	1.28	....	3165	3147	.138	1.10	.011	.322	.17	.319	.080
955	1.28	....	3130		.145	1.10	.011	.322	.17	.319	.080
963	1.28	....	3460	3357	.151	1.10	.012	.394	.17	.336	.077
963	1.28	....	3255		.151	1.10	.012	.394	.17	.336	.077
947	1.28	....	2310	2310	.120	1.15	.014	.290	.21	.333	.080
1018	1.28	....	3200	3080	.164	1.15	.042	.138	.49	.410	.093
1018	1.28	....	2960		.148	1.15	.042	.138	.49	.410	.093
1028	1.28	....	3130	3145	.175	1.15	.040	.160	.46	.440	.108
1028	1.28	....	3160		.169	1.15	.040	.160	.46	.440	.108
767	1.26	1.27	2727	2815	.135	1.20	.020	.144	.57	.668	.074

TABLE VI*b*.—TRANSVERSE TESTS ON TITANIFEROUS CAST IRON—Con.

Cast No.	Nominal Diameter, Inches Width	Height	Breaking Load, Pounds	Average Breaking Load	Ultimate Deflection, Inches	Analysis Si.	S.	P.	Mn.	Ti.	V.
767	1.26	1.28	2903	2815	.135	1.20	.020	.144	.57	.668	.074
957	1.28	....	3275	3272	.160	1.25	.013	.358	.18	.351	.080
957	1.28	....	3270		.157	1.25	.013	.358	.18	.351	.080
964	1.28	....	2970	3092	.138	1.25	.011	394	.17	.336	.077
964	1.28	....	3215		.161	1.25	.011	.394	.17	.336	.077
952	1.28	....	3260	3320	.173	1.30	.014	.322	.17	.319	.080
952	1.28	....	3380		.163	1.30	.014	.322	.17	.319	.080
1023	1.28	....	3590	3590	.181	1.30	.039	.168	.47	.427	.106
946	1.28	....	3460	3195	.168	1.35	.015	.290	.21	.333	.080
946	1.28	....	2930		.139	1.35	.015	.290	.21	.333	.080
959	1.28	....	3220	3135	.165	1.35	.011	.358	.18	.351	.080
959	1.28	....	3050		.145	1.35	.011	.358	.18	.351	.080
965	1.28	....	2200	2160	.131	1.35	.014	.394	.17	.336	.077
965	1.28	....	2120		.150	1.35	.014	.394	.17	.336	.077
902	1.28	....	2770	2770	.160	1.40	.046	.216	.55	.332	.054
958	1.28	....	3150	3150	.145	1.40	.013	.358	.18	.351	.080
797	1.28	....	2950	2950	.156	1.45	.022	.164	.50	.498	.080
903	1.28	....	3100	3025	.169	1.45	.044	.212	.54	.332	.054
903	1.28	....	2950		.152	1.45	.044	.212	.54	.332	.054
945	1.28	....	3200	3170	.144	1.50	.016	.290	.21	.333	.080
945	1.28	....	3140		.140	1.50	.016	.290	.21	.333	.080
969	1.28	....	3230	3230	.144	1.55	.014	.386	.16	.393	.071
911	1.28	....	3100	3050	.135	1.55	.042	.208	.48	.317	.061
911	1.28	....	3000		.150	1.55	.045	.208	.48	.317	.061
1030	1.28	....	3340	3340	.160	1.75	.035	.147	.50	.440	.108

Average breaking load Si .00–0.99%, 3002 lbs.
" " " " 1.00–1.49%, 3014 "
" " " " 1.50–1.99%, 3197 "

TABLE VII.—COMPARATIVE TESTS OF MACINTYRE AND BUFFALO (ALL LAKE ORE) IRONS.

Index Mark to Composition	Percentage in Mixture of		Transverse Strength pounds	Shrinkage	Chill	Analysis								
	Pig Iron	Stove Plate Scrap				Si.	S.	P.	Mn.	G.C.	C.C.	Ti.	V.	Cr.
T-1	Pig	...	....	....	....	1.85	.035	.609	.48	3.23	.54	.50	.062	.035
B-1	Pig	...	....	....	....	1.85	.024	.569	.80	3.15	.61	.109	.036	....
T-1-1	100	...	4295	1/8″	O″	1.80	.033	.56	.47	3.12	.55	.281	.066	.033
B-1-1	100	...	3919	1/8″	H. L.	1.80	.023	.58	.76	3.04	.50	.069	.024	.023
T-1-2	50	50	Bar lost	1/8″	O″ to 1/16″	2.15	.099	.63	.46	2.68	.64	.114	.055	.024
B-1-2	50	50	4051	1/8″	H. L. to 1/16″	2.17	.059	.728	.64	2.90	.49	.066	.040	.024
T-2	Pig	...	....	....	....	2.00	.027	.633	.44	3.28	.51	.494	.058	.033
B-2	Pig	...	....	....	....	2.01	.028	.565	.70	3.13	.56	.134	.041	....
T-2-1	100	...	4023	1/8″	O″	2.00	.021	.612	.48	3.40	.44	.276	.051	.038
B-2-1	100	...	3750	1/8″	O″	2.00	.03	.564	.63	2.79	.53	.086	.033	.019
T-2-2	50	50	3741	1/8″	O″ to H. L.	1.95	.058	.71	.51	2.77	.48	.126	.043	.021
B-2-2	50	50	3770	1/8″	3/32″ to 1/16″	2.00	.062	.70	.58	2.85	.57	.069	.034	.019
T-2-3	30	70	Bar lost	1/8″	1/32″ to 1/16″	2.20	.071	.726	.50	2.82	.49	.136	.041	.017
T-3	Pig	...	....	....	....	2.50	.021	.62	.50	3.43	.38	.595	.067	.039
B-3	Pig	...	....	....	....	2.63	.018	.575	.76	3.25	.54	.165	.033	....
T-3-1	100	...	4047	1/8″	O″	2.35	.023	.556	.51	3.42	.25	.45	.054	.037
B-3-1	100	...	3835	1/8″	O″ to 1/32″	2.55	.020	.58	.73	3.00	.44	.116	.034	.025
T-3-2	50	50	4106	1/8″	O″ to H. L.	2.15	.061	.64	.51	3.06	.16	.205	.049	.021
B-3-2	50	50	3617	1/8″	3/32″ to 1/16″	2.45	.063	.692	.62	3.15	.25	.089	.037	.024
T-3-3	30	70	3957	7/64″	1/16″ to 1/8″	2.10	.083	.744	.53	2.88	.42	.145	.041	.019
T-4	Pig	...	....	....	....	2.70	.015	.65	.32	3.47	.23	.599	.069	.038
B-4	Pig	...	....	....	....	2.79	.027	.569	.72	3.50	.20	.132	.038	....
T-4-1	100	...	3890	1/8″	O″	2.65	.014	.51	.30	3.25	.19	.516	.064	.035
B-4-1	100	...	3657	1/8″	H. L.	2.65	.03	.56	.70	3.00	.42	.073	.037	.024
T-4-2	50	50	3975	1/8″	O″	2.40	.06	.618	.39	3.22	.21	.284	.055	.032
B-4-2	50	50	3563	1/8″	3/32″ to 1/16″	2.40	.06	.69	.59	2.75	.54	.06	.036	.017
T-5	Pig	...	....	....	....	3.00	.021	.642	.41	3.59	.25	.569	.075	.036
T-5-1	100	...	3887	1/8″	O″	2.95	.020	.57	.41	3.55	.21	.529	.065	.039
T-5-2	50	50	4430	1/8″	H. L. to O″	2.48	.055	.66	.46	3.10	.13	.265	.051	.023
T-5-3	30	70	3716	7/64″	3/32″ to 1/16″	2.30	.073	.73	.49	2.85	.46	.149	.048	.018

T = MacIntyre Iron. B = Buffalo Iron. H. L. = Hair Line.

Test Bars were cast in damp sand, without sinker head. Transverse strength with 1¼″ round bar with 12″ supports. Shrinkage was in 12″ cast iron yoke. Chill Bar 1½″ square against a 1½″ square chill.

In the column headed Index Mark, the marks T-1, B-1, etc., indicate the pig iron from which the mixtures were made, only the analysis before melting being given. Marks T-2-3, B-4-2, etc., indicate the mixture made, the analysis given being the composition after melting.

TABLE VIII.—ANALYSES OF IRONS MADE FROM ALL LAKE ORE.

Si.	S.	Ti.	Si.	S.	Ti.	Si.	S.	Ti.	Si.	S.	Ti.
1.42	.030	.069	1.20	.024	.080	1.60	.018	.094	1.16	.026	.080
1.69	.030	.100	1.43	.020	.100	1.30	.029	.087	1.08	.037	.074
1.23	.024	.076	1.44	.026	.100	.92	.038	.062	1.52	.021	.098
1.20	.030	.085	1.42	.026	.102	1.10	.031	.069	1.56	.015	.101
1.32	.037	.071	1.42	.027	.102	1.89	.024	.115	1.46	.021	.097
1.25	.035	.076	1.96	.017	.124	2.10	.022	.131	1.00	.032	.055
1.35	.024	.092	1.98	.023	.124	1.80	.017	.101	1.58	.028	.081

TABLE IX.—ANALYSES OF PIG IRON.

Port Henry Irons.

Si.	S.	P.	Mn.	G. C.	C. C.	Ti.	V.
1.80	.024	.640	.70	3.38	.59	.089	....
2.12	.031	.648	.61	3.23	.49	.261	.021
2.53	.022	.647	.54	3.31	.50	.360	.023
2.70	.023	.629	.51	3.09	.31	.310	....
2.95	.015	.638	.43	3.39	.25	.410	.023
3.15	.020	.620	.54	3.50	.17	.340	....

Standish Irons.

Si.	S.	P.	Mn.	G. C.	C. C.	Ti.	V.
.80	.071	.018	.14	1.67	1.55	.050	.011
1.13	.020	.019	.13	2.73	.76	.122	.034
1.50	....	....	....	....	....	.205	.045
1.60	.014	.018	.15	3.10	.54	.149	.040
2.00	.013	.020	.15	3.47	.46	.225	.048
3.25	.013	.021	.16	3.35	.17	.357	.058
4.05	....	....	....	....	....	.214	.053
6.35	....	....	....	....	....	.255	.045
9.59	....	....	....	....	....	.219	.034

TABLE Xa.—Results of Use of Titaniferous Pig Iron in Open-Hearth Furnace.

Number of Heat	2,132	2,133	2,134	2,135	2,138	2,139	2,140	4,342
Charge in Pounds								
Pig Iron, Northern	20,140	20,320	40,040	40,040	62,260	62,460	58,960	58,620
Other Pig Iron	34,040	34,260	14,080	14,620	......	......	3,080	......
Cast Iron Scrap	......	10,200	19,820	10,080	......	......	......	......
Steel Scrap:								
Sheets and skeleton	14,550	12,200	10,000	6,560	27,100	10,000	......	8,500
Mixed scrap	......	5,620	......	......	......	......	4,920	......
Steel tires	......	......	......	6,480	......	......	......	......
Beams, angles, rails, springs and carparts	31,050	......	37,900	15,420	32,160	52,060	......	34,450
Works scrap	14,460	42,240	12,250	31,250	2,540	......	57,830	23,050
Total charge, lbs	124,540	124,840	124,090	124,810	124,060	124,520	124,790	124,620
Ferro-manganese, lbs	600	650	1,150	600	750	700	700	600
Cinder, lbs	......	......	5,000 C	8,000 C	...... Ore	4,000 Ore	6,000	4,000 C
Extra pig iron, lbs	......	5,000	......	......	......	......	......	......
Gross metal, lbs	125,140	130,490	128,240	130,210	124,810	127,620	129,090	127,620
Ingot production, lbs	105,960	116,880	113,550	116,140	109,570	112,090	115,330	110,110
Limestone, lbs	17,000	16,000	13,500	14,500	13,500	13,500	13,500	9,000
Fluorspar, lbs	800	800	750	800	800	800	1,000	900
Lost time	......	......	1 hr., 30 min. high sulphur	45 min. no stock	2 hrs. no stock	45 min. repairing bottom	......	......
Interval	45 min.	35 min.	50 min.	1 hr. 45 min.	3 hrs. 25 min.	1 hr. 20 min.	50 min.	1 hr. 5 min.
Began charging	9:05 A. M.	9:05 P. M.	10:30 A. M.	12:45 A. M.	4:10 A. M.	8:45 P. M.	10:00 A. M.	11:30 A. M.
Finished charging	1:00 P. M.	1:45 A. M.	1:45 P. M.	4:10 A. M.	11:30 A. M.	12:10 A. M.	1:20 P. M.	2:30 P. M.
Tapped	8:30 P. M.	9:40 A. M.	11:00 P. M.	2:55 P. M.	7:25 P. M.	9:10 A. M.	11:15 P. M.	10:15 P. M.
Time in furnace	11 hrs. 25 min.	12 hrs. 25 min.	12 hrs. 30 min.	14 hrs. 10 min.	15 hrs. 15 min.	12 hrs. 25 min.	13 hrs. 15 min.	10 hrs. 45 min.
Began stripping	9:10 P. M.	10:25 A. M.	11:45 P. M.	5:20 P. M.	9:35 P. M.	9:55 P. M.	12:15 P. M.	11:30 P. M.
Finished stripping	10:10 P. M.	11:25 A. M.	12:30 A. M.	5:55 P. M.	10:30 P. M.	10:30 A. M.	12:50 P. M.	12:30 P. M.
Charged into pits	10:25 P. M.	11:30 A. M.	....	Lost 1:00 hr.	10:15 P. M.	10:15 A. M.	1:15 A. M.	12:30 P. M.
Rolled at mill	4:00 A. M.	12:30 to 1:30 PM.	....	no cinder	5:00 to 6-20 A.M.	2:00 to 3:15 P.M.	6:20 to 7:15 A.M.	5:00 to 6:00 A. M.
Shape	11" x 11" billets	11" x 11" billets	billets	15" beams	6.75"x5.5" billets	15" Channels	15" beams	15" beams
How steel rolled	O. K.	O. K.	O. K.	Bad	O. K.	Bad	Medium	O. K.

Partial analysis of Pig Iron:

No. of Heat	Si.	S.	P.	Mn.
2133	.68	.024	.78	1.50
2134	.44	.036	.78	1.50
2135	.60	.046	.88	1.35
2138	.86	.027	...	....

Northern pig iron analyzed P. 192, Mn. 1.12, Ti. .445, V. .066.

On heats 2132 to 2135, inclusive, no difference in the working of the heats in the furnace. On heats 2138 to 2140, inclusive, and heat 4342 the bath foamed a little during the heat.

TABLE Xb.—ANALYSES OF STEEL.

Number of heat	2132	2133	2134	2134	2135	2138	2139	2140	4342
Carbon	.19	.18	.15	.15	.19	.18	.18	.18	.19
Manganese	.43	.40	.41	.41	.40	.43	.42	.40	.40
Sulphur	.039	.029	.045	.045	.042	.045	.043	.045	.030
Phosphorus	.020	.018	.015	.015	.023	.021	.023	.025	.023
Titanium	none	none	none	none	none	none	none	none	none
Vanadium	none	none	none	none	none	none	none	none	none
Elastic limit, pounds	36,400	35,660	35,930	40,740	37,350	34,980	35,360	35,680	32,880
Tensile strength, pounds	61,200	60,210	59,310	63,340	63,140	56,390	58,390	61,980	61,640
Elongation in 8 inches	30 %	32 %	31 %	26 %	31 %	33 %	34 %	29 %	33 %
Reduction of area	49.7 %	57.6 %	52.4 %	51.1 %	54.4 %	59.8 %	53.1 %	55.3 %	52.2 %
Character of fracture	silky angular	silky cup	silky angular	silky angular	silky angular	silky cup	silky angular	silky ½ cup	silky cup
Section	8 x 6 x ¾"	8 x 8 x ½"	12"x31½ lb.	2½" x 2 x 3/16"	15" x 50 lb. beams	6 x 3½ x ⅜"	15" x 40 lb. channels	15" x 80 lb. beams	15" x 95 lb. beams

Heat 2135—Eight ingots rolled into beams, the remainder cracked on the flanges.
Heat 2139—Six ingots rolled into channels, the remainder cracked on the flanges.

TABLE Xc.—ANALYSES OF SAMPLES TAKEN DURING HEATS.

SAMPLE	Number of Heat	Carbon	Manganese	Sulphur	Phosphorus
1st Preliminary test...	2132	.37	.25	.061	.056
2nd Preliminary test...	2132	.24	.22	.034	.019
3rd Preliminary test...	2132	.19	.27	.046	.017
1st Preliminary test...	2133	.29	.23	.057	.019
2nd Preliminary test...	2133	.15	.19	.046	.014
3rd Preliminary test...	2133	.16	.36	.034	.011
1st Preliminary test...	2134	.96	.35	.055	.123
2nd Preliminary test...	2134	.40	.22	.067	.065
3rd Preliminary test...	2134	.11	.26	.053	.014
1st Preliminary test...	2135	1.00	.21	.052	.045
2nd Preliminary test...	2135	.53	.15	.054	.023
3rd Preliminary test...	2135	.13	.13	.052	.011
1st Preliminary test...	2138	.90	.23	.060	.097
2nd Preliminary test...	2138	.22	.14	.055	.017
3rd Preliminary test...	2138	.11	.12	.040	.014
1st Preliminary test...	2139	.22	.16	.070	.061
2nd Preliminary test...	2139	.10	.15	.041	.019
3rd Preliminary test...	2139	.12	.11	.041	.020
1st Preliminary test...	2140	.29	.21	.055	.048
2nd Preliminary test...	2140	.15	.17	.047	.029
3rd Preliminary test...	2140	.14	.13	.045	.023
1st Preliminary test...	4342	.39	.27	.035	.207
2nd Preliminary test...	4342	.23	.18	.033	.039
3rd Preliminary test...	4342	.14	.17	.030	.023

No titanium or vanadium was found in any of the samples.

TABLE XI.—TEST TO DETERMINE OXIDATION OF METALLOIDS, TITANIFEROUS PIG IRON MELTED IN GRAPHITE CRUCIBLE WITH ORE ADDITIONS.

Weight of Iron, Lbs.	Additions Old Bed Concentrates, Grams	Time held	Si.	C.	Mn.	Ti.	V.	Cr.
20½	00	10 minutes in ladle........	2.35	3.75	.42	.41	.053	.016
20½	75	3 minutes in ladle........	2.30	....	.40	.38	.048	....
20½	75	3 minutes in ladle........	2.30	....	.41	.375	.045	....
20½	75	60 minutes in furnace.....	1.95	....	.36	.214	.040	....
20½	75	3 minutes in ladle........	1.90	....	.34	.205	.040	....
20½	75	35 minutes in furnace.....	1.70	....	.32	.165	.032	....
20½	150	25 minutes in furnace.....	1.45	3.13	.29	.141	.032	.014
13½	700	melted and held 20 minutes.	1.25	3.51	.31	.224	.050	.007
10	1200	melted and held 60 minutes.	.32	3.53	.11	.043	.007	.016
		290 minutes..............	.06	3.60	.05	.017	.007	.018

THE USE OF TITANIFEROUS ORE IN THE BLAST FURNACE

Arthur H. Lee

Superintendent, Blast Furnaces, Lackawanna Steel Company, Lackawanna, N. Y.

Mr. Bachman, in his very complete paper on the use of titaniferous ore in the blast furnace, has treated a subject in which he alone has had practical experience on a commercial scale. The test that he made seems to have been carried on in a thorough and systematic way. My own experience is limited to a one day visit at Port Henry, N. Y., when Mr. Bachman was making his test; and a period a number of years ago at the Scranton furnaces when we used large amounts of Adirondack ores which contained very small percentages of titanium, so that I cannot give much except my opinion.

The subject of the use of titaniferous ores is sure to come to the front in the near future, on account of the large bodies of this ore which have never been mined. In 1890, or thereabouts, Rossi made some experiments on a small scale, which showed there was no trouble in using ores containing as high as 35 to 40 per cent. TiO_2. Shortly after that, due to the development of the Lake Superior ores which seemed inexhaustible, the subject was dropped until Mr. Bachman's experiment at Port Henry.

The exhaustion of high grade ores low in phosphorus in the Lake district will eventually bring about the use of titaniferous ores, which as a rule are apt to run very low in phosphorus. Until recently ores containing over 1 per cent. titanium were supposed to be troublesome, due to the belief, which was based on incomplete observation and hearsay, that high fuel was needed, and infusible compounds were formed which built up the furnace hearth. In early days ores containing titanium were used in small charcoal furnaces and it seems it made no difference whether the ores had much or little titanium. As furnaces got larger

and charcoal was difficult to obtain, and as ores high in titanium were lower in iron, richer ores were used with better results, which at that time was naturally credited to the dropping out of the titanium. This prejudice grew so that furnace men fought shy of titaniferous ores, especially as soft and easily reducible Lake ores were so readily obtained.

In Scranton, Pennsylvania, during the eighties, the Lackawanna Iron and Steel Co. used large quantities of magnetic ores from the Adirondack region, which contained varying small percentages of titanium. The titanium in the ore invariably was plainly evident in the Salamander when the furnace was blown out. Our furnaces were all troubled then with high bottoms, which we blamed to the deposits of infusible compounds. This was before the days of fast driving, when all furnaces, especially those which used anthracite coal as we did, had high bottoms. In the nineties, when we used a large percentage of coke and drove the furnaces faster, the furnace bottoms cut out. We then wished that we had some high titaniferous ores to build them up and stop breakouts. Since that time I have often thought that in a modern blast furnace titaniferous ores would not give any trouble, and after my visit to Port Henry last July, where I saw that furnace working on 25 per cent. of an ore containing 13 per cent. TiO_2, I am thoroughly convinced that no trouble would result from working these ores, and that the TiO_2 in the ores should be treated as SiO_2, in the ratio of 100 parts TiO_2 being equal to 75 parts SiO_2.

Referring to Mr. Bachman's report, his laboratory experiments, showing the relative reducibility of ores, are very interesting. The melting points of slags with different amounts of TiO_2 under conditions not as favorable as obtained in a blast furnace, show that the slags were not infusible, as had been erroneously supposed. In the test the furnace would probably have worked smoother, from our experience here, if it had 8 tuyeres evenly spaced instead of 12, and a deeper hearth. The furnace seems to have been in poor shape when the test was started, which accounts

for a lot of the trouble which occurred from time to time. This, to my mind, was a good thing for a fair test, because if the ore was difficult to handle, these troubles would have been magnified, and yet the reverse seems to be true.

The troubles Mr. Bachman speaks of, such as dirty hearth, cinder about the tuyeres, are troubles which other furnaces are liable to, due to various causes not chargeable to titaniferous ores. The conclusions which he comes to in summing up his report, I thoroughly agree with, as they seem logical from the complete data which he gives.

THE USE OF TITANIFEROUS ORE IN THE BLAST FURNACE

RICHARD HENRY LEE

Superintendent, Lebanon Furnaces, Pennsylvania Steel Company, Lebanon, Pa.

There is little to add to Mr. Bachman's very complete paper on titanic ores. When I was in Colorado there was in the stockyard a pile of titanic ore which had been brought there many years before. It had been accused of giving trouble in the furnace, and the use of it had been discontinued. Some of the ore was used at various times by Mr. Nau for fixing the puddle furnaces, and a great amount of it was finally used in foundations.

The air in Colorado is so dry that all ores in the stockhouse lose the greater part of their moisture. In operating, the ore piles always show a great loss in weight compared with the weight as shipped from the mines. When a pile was approaching exhaustion, the custom was to fill more or less flue dirt in the burden and charge it as ore, to make the amount used correspond roughly to the original weight received.

On one occasion it occurred to us to try to use up the pile of titanic ore which had been charged off the books many years before. This ore was a magnetite running about 35 per cent. in iron, and 12 per cent. in SiO_2. A small quantity, one buggy in a charge of twelve, was put on the furnace. In a day or two, for some cause or other, the furnace went off. This frequently happened and always from the same cause, irregular coke. But the titanic ore, while not blamed for the change, was under suspicion and was taken off.

Some months afterward, the same ore conditions coming up again, I decided to try the experiment again and to keep it up regardless of any changes that the furnace might make, because I was convinced that the soft and irregular coke

made all the trouble we ever had with the furnaces and that more or less titanic ore would make no appreciable difference. I had read with a great deal of interest M. Rossi's experiments with titanic ores, which at that time was all the literature of any value on the subject, and decided to consider the TiO_2 simply as an acid along with the SiO_2 and Al_2O_3 and flux accordingly.

Except when making low sulphur iron the slag we usually ran on was a 48 per cent. SiO_2 and Al_2O_3 slag, and consequently that proportion of acids was kept. As such a slag is fusible, if the TiO_2 had a tendency to increase the refractoriness there was some margin to go on. Small amounts were used in the charge until I was convinced that the TiO_2 was not making any apparent difference in the general working. Then I used greater quantities for different lengths of time, sometimes charging seven or eight buggies, always being careful in every increase not to keep it on so long that the furnace could not be easily brought around if things went badly.

I was very curious to know whether the TiO_2 was as difficult to work as was generally supposed but never found any particular difference in the working of the furnace both in the regular ores and when on the TiO_2 mixture. The furnace was blown up to the capacity of the blowing engines. These were the S. P. Morris make and very old; 25,000 cu. ft. engine measurement was about as much as could be gotten out of them, and the pressure could only go to 8 pounds without stalling them. The furnace was 10′ hearth, 17′ bosh, and 75′ high. The great point in working TiO_2 ores, I believe, is to regard the TiO_2 as an acid and flux it instead of only fluxing the SiO_2 and Al_2O_3. The sulphur in our coke was only 0.60, so that an acid and fusible cinder could always be used. And I judged that the TiO_2 could raise the melting point of the cinder considerably without giving trouble. The slag was always fluid, nor did there seem to be any bottoming. The tendency, if any, was the other way.

The ore, however, differed very greatly from that used at Port Henry. Although a magnetite, it was mostly in lumps the size of a man's fist, or a little larger, or else in

fine soft particles somewhat similar to old range lake ores, or the fines from Cornwall ore, which offer hardly any resistance to the passage of the furnace gases. No screen tests were made, as they were not necessary with the Colorado ores. Mr. Bachman's ores were much finer, and the fine particles have a tendency to pack among the interstices of the coke, making it difficult to get good penetration and distribution of the gases through the mass.

The hanging of the cinder around the tuyeres and generally dirty hearth conditions which he describes, are often met with in working 100 per cent. nodulized concentrates from Cornwall ores, when from heavy burdens or unusually fine nodules the melting point in the furnace is brought down too close to the tuyeres. In such cases, while the iron is hot, the furnace will not drive, and things are generally just about what he described at Port Henry. I have found that in these conditions giving the furnace more wind and lightening the burden are the only means of getting relief. From a number of these experiences in working nodules we have learned the importance of getting the melting point just right, and this condition probably exists with the mixture of Port Henry magnetites and Sanfords ore.

From the experiences I have had, I thoroughly agree with the conclusions that Mr. Bachman has so well worked out as to the commercial feasibility of using titanic ores in the blast furnace. I believe, also, that in working titanic ores the presence of MgO in the slag will be found to be necessary.

MODERN DEVELOPMENT OF THE IRON AND STEEL INDUSTRY IN THE SOUTH

Thomas K. Glenn

President, Atlanta Steel Company, Atlanta, Ga.

The States south of the Ohio and east of the Mississippi, with their half-million square miles of area, contain a wealth great enough for a continent—a wealth so vast, so varied in its elements and character, so advantageously placed for development, that these States alone can sustain a population far greater than the population of the United States to-day. * * * It was the building of an empire in the West that relieved and enriched the East as well as the West. The enormous energies, the "plant" used in that task, unparalleled in the magnitude of the work and the greatness of the reward to all, is now seeking a new field for investment, and there is no spot on earth sufficient for it and within its reach but the South. * * * I do not consider that there ever existed in the West, great as its wealth is, nor any other portion of the country, anything like the natural wealth of the South. A very large part of the South is blessed with a climate unexcelled, if equalled, elsewhere in the world. As to the mountainous region of the South, it is richer in natural wealth and in advantages for the development of that wealth; it has a finer climate, better water and higher condition of health than any region of which I have any knowledge, and is, withal, one of the most beautiful regions in the world.

(Extract from a letter by the late Hon. Wm. D. (Pig Iron) Kelley, of Pennsylvania, to Richard H. Edmonds.)

If what Mr. Kelley has stated is true, we will consider for a short while what we have done with these wonderful natural advantages. Nearly 200 years ago, in 1732, we find a Mr. Washington, no doubt the father of George, mining and selling iron ore in Virginia at 20 shillings per ton. A little later, it is said that Thomas Jefferson was making nails at the rate of about a ton per month at considerable profit. "So far as can be determined the Southern States made almost exactly one-fifth of the iron produced in 1810, and this proportion increased quite steadily, reaching its maximum probably between 1840 and 1850." Prior to 1856 there were in Virginia 88 charcoal furnaces, 59 forges and 12 rolling mills. This was also true to a greater or less extent in Maryland, North and South Carolina, Georgia, Alabama and Tennessee, and continued until the close of the Civil War, when the loss of slaves, financial embarrassments and

exhaustion of the charcoal put an end to it. "In 1860 the Southern States were making something over 120,000 tons of pig iron annually. It is probable that during 1861 and 1862 this was greatly exceeded, but from that time on the output fell off as furnaces and mills were destroyed." To one who was not in close touch with the reconstruction period of the South, it is difficult for them to understand why, with the beginning that had been made prior to 1863, a more rapid development has not taken place, and more in keeping with that in other sections of the country. The facts are that this section of our country was broken in spirit; in finances it was a complete wreck, and there was a dearth of men to even cultivate the farms. But someone has said, "Look not mournfully into the past, it comes not back again; wisely improve the present, it is thine; go forth to meet the shadowy future without fear and with a manly heart." The South has made a noble effort to overcome the ravages of war, and how well she has succeeded we shall presently see.

Recovering from the Civil War.

"In 1870 the South had recovered only so far as to produce a little more than 8 per cent. of the American total iron output, but in the decade which followed progress was much more rapid, so that by 1875 the South's proportion had risen to over 12 per cent., which was about held in 1880." It was during this period, in 1876, that the first coke pig iron was made at the Oxmoor Furnace in the Birmingham District, and we might say that it was from this date that the modern development began. Let us consider just here the possibilities of the South in the way of raw material, for without good coal and ore no very material progress can be made.

The Raw Material of the South.

Those who are supposed to be in position to know say that the Southern States have almost an inexhaustible supply of good coking coal that will probably outlive the supply

of iron ore, and that the lack of this can in no wise hinder the future iron and steel development of this section. While there is no way of determining, yet it is given as an estimate by the U. S. Geological Survey that the coal fields of the South probably contain one-half of the total of the United States, and more than twice the coal of the whole of Europe.

In 1880	the South	was	producing	about	10%	of	the coal	mined	in the	U. S.
" 1890	"	"	"	"	15%	"	"	"	"	"
" 1900	"	"	"	"	20%	"	"	"	"	"
" 1910	"	"	"	"	24%	"	"	"	"	"

So the South has more than kept pace with the balance of the country in this respect.

No two authorities seem to agree on the amount of good workable iron ore in the Southern States (for estimating coal and iron deposits is largely a matter of guess work at best), but they are all impressed with the fact that there seems to be an almost inexhaustible supply, sufficient at least for a hundred or more years to come; so that in considering the iron and steel possibilities of the South we need have no immediate concern about the supply of raw material, although some of it may not be of so excellent a quality as is found in other sections of the country.

The Iron and Steel Development of the South.

In considering the South's commercial development in iron and steel, it might be viewed from five standpoints:

(1) "That until very recently all of the South's output had to be marketed in the form of pig iron, and that even now most of it is sold in that form.

(2) "That the bulk of the output is marketed at points far from the furnaces and is subject to heavy freight charges.

(3) "That the market price of Southern pig iron is always lower, and usually much lower, than that of similar grades at Northern and Eastern furnaces."

(4) That the production of iron in the past ten years has remained about the same, while that of the country at large has shown a marked increase.

(5) What can be done to improve all of these conditions?

For the purpose of comparison, it is interesting to note the production of pig iron in the South for the past several years as compared to other sections of the country. In the South is included the States of Alabama, Virginia, Tennessee, Maryland, West Virginia, Kentucky, Georgia, Texas, North and South Carolina and Mississippi:

Year	South Tons	Percentage of Increase	United States Tons	Percentage of Increase	South's Percentage of Total
1883	624,339	..	4,595,510	..	13.6
1893	1,567,299	151	7,124,502	55	22.0
1903	3,237,079	106	18,009,252	152	17.9
1913	3,285,957	1.5	30,966,152	71	10.6

From these figures it will be seen that the South's production of pig iron has remained about the same for the past ten years, while the United States has made an increase of over 70 per cent. and that the South's percentage of the production of the whole has, during the same period, fallen from 17 per cent. to 10 per cent., a reduction of 7 per cent.

The South's Commercial Development.

In order to get at a fair comparison, we will take the South's progress in other lines:

		South	Percentage of Increase	United States	Percentage of Increase	South's Percentage of Total
Val. of Mfg. Products..	1900	1,860,000,000		13,000,000,000		14.3
	1909	3,158,000,000	69	20,000,000,000	53	15.8
Val. of Agl. Products..	1900	1,564,000,000		4,717,000,000		33.2
	1909	3,297,000,000	110	9,532,000,000	102	34.6
Resources of Nat. Banks	1900	705,000,000		5,048,000,000		14.0
	1912	2,112,000,000	198	10,965,000,000	117	19.2

In 9 years manufactured products have shown an increase of 69 per cent., Agricultural Products 110 per cent., and in 12 years National Bank Resources 198 per cent., and in each instance the percentage of increase has been greater in the South than other sections of the country, as will be shown by the above table.

Iron and Steel Production and Prices.

Before going into the cause for all of this, it might be best to consider the selling price of pig iron in the Birmingham District as compared to Philadelphia, for instance, and what progress has been made in the development of the steel industry:

	Birmingham	Philadelphia	Difference
Average price of No. 2 Foundry, 1912	$11.55	$16.06	$4.51 per ton
" " " " 2 " 1913	11.69	16.57	4.88 " "

Although the start was late as compared to other sections of the country, the South can give a little better account of herself in the production of steel than in pig iron. The first open hearth steel was made in the Birmingham District in 1888 by the Henderson Steel & Manufacturing Company. Col. J. W. Bush, in giving an account of same, says: "After many tedious delays the furnace was fired, and in three hours and forty minutes the first ton of Alabama steel was molded into ingots on the 8th day of March, 1888. When this ton of steel was made the stock of the company soared skyward; 1,200 for 100 was given in some instances. While we had steel we had no furnace left. Our furnace lining was of fire brick and dolomite. The heat was so intense that the lining and brick fused and went out with the steel. In our enthusiasm we overlooked this important difficulty and proceeded at once to organize another and larger company."

Year	Bessemer	Open Hearth	Total	Percentage of Increase	In United States	Percentage of Increase
1901.....	736,547	179,548	916,095	..	13,473,595	..
1913.....	673,063	1,183,977	1,821,040	98	31,300,874	132

For the year 1901 the production of Bessemer and Open Hearth Steel was 916,000 tons and in 1913 it had increased to 1,821,000, or about 98 per cent., while the increase in the whole country during the same period was 132 per cent.

From this comparison it will be noted that during the 10 or 12 years just passed the production of steel has shown an increase of 98 per cent., Manufactured Products 69 per cent., Agricultural Products 110 per cent., National Bank Resources 198 per cent., while the production of iron has remained the same.

The Need of a Home Market.

The reason why the development in iron has not been faster and in keeping with other sections of the United States is that "there has not been a sufficient demand for it at home due to the woeful lack of manufacturing industries that use pig iron. The consumption of pig iron in the United States is about 650 pounds (per capita), while in the South I estimate that it is not over 150 pounds. The difference represents the backwardness of the South in the manufacture of finished forms of iron and steel. The present approximate consumption of pig iron in the South is 1,800,000 tons. If the South manufactured all the finished iron and steel that it now uses it would probably consume not less than 5,000,000 tons of pig iron. At the normal per capita consumption the South should use about 10,000,000 tons of pig iron."

"Is there a remedy for this state of affairs that will permit the Southern Iron Trade to share in the general growth and prosperity of the Southern District? Yes, it is to sell the production in its natural market. Hitherto the greater portion of Southern pig iron produced has been sold in the Northern Market; and this fact has been used many times as evidence of the wonderfully low cost of production of the Southern product. Does foundry iron sell at $13.00 Birmingham and at the same time sell at $17.35 in Chicago because it has been produced $4.35 cheaper in Birmingham than in Chicago? Not necessarily. Birmingham makes more iron than it can use, and the surplus must be marketed. Chicago needs more iron than it makes and can use the surplus Birmingham product at her price, but that the profit on iron used in Chicago which was made in Chicago is greater than the profit on iron made at Birmingham and

freight paid to Chicago, is shown by the figures in pig iron production in Chicago as against the stationary production in the Southern District. It is too much to expect of one iron making district that it can pay $4.35 per ton, or about 25 per cent. of the total selling price as freight, to foundries situated close to the furnaces of another good iron producing district and make as large profits—the handicap is too great."

"But what is the natural market for Southern iron? It is the South itself, supplemented by export trade. Put the surplus pig iron produced in the South into steel. The larger portion of the steel used in the South is shipped in from the Northern District. On the principal steel products, Birmingham can reach with freight no higher than Chicago or Pittsburgh, a territory inhabited by 30 per cent. of the population of the United States. The rates to tidewater are lower than from either Pittsburgh or Chicago. True, the population of this territory uses less steel per capita than the average population of the United States, but an increase in this respect is noted. It is true, too, that during the transition period the orders will be for small lots and of a diversity of sizes that will militate against the highest mill efficiency; but these conditions will steadily improve as the small industries grow larger. The production of steel ingots in the South is steadily increasing. Plants are now being constructed which will increase the production materially. The merchant furnaces will find an increased local market for their iron products as the quantity of the steel made in the South increases, for with it there will be an increase in the fabricated steel products which use cast iron parts as well as steel parts."

"If a portion of the iron and steel produced could be regularly exported, the trade would be upon a more substantial basis than if dependent upon the domestic market entirely."

We have five steel plants in the South when we should have four times that many, and three of these are of very small capacity indeed. We have less than one half as many foundries per capita as in the other sections of the country, while the showing in pipe works is only a little bit better.

The Future of the South's Iron and Steel Trade.

"As to the future of the iron and steel trade in the Southern District, the past marks a period where the splendid vitality of the iron trade not only kept out irons of other districts but shipped iron into them, while the problem of making steel from Southern iron was being worked out. It has been conclusively demonstrated that from it steel for rails, plates, sheets, structural shapes and bars and wire products can be made of as good a uniform quality as is made to-day anywhere in the world."

"How is it that Birmingham with its reputed possibilities of making the lowest cost pig iron, presents such a poor showing in the growth of its iron industries when compared with the Northern District? An analysis of the South discloses the following facts:

(1) That the low cost which had been claimed for making pig iron in the Birmingham District had been due in part to skimming the cream instead of taking the average cost, in part to improper cost methods of bookkeeping, and in part to the low cost of labor which prevailed here."

"A limited quantity of pig iron can be manufactured very cheaply in the Birmingham District."

"With the present equipment of mines, transportation methods and furnaces in the Birmingham District, the average cost of making pig iron is not very different from the average cost of making pig iron in Youngstown and Chicago, and Pittsburgh might also be included by those companies which, like the companies here, own all their raw material supplies."

"This statement will probably come as a surprise and disappointment to those who are familiar with the so-called wonderful advantages of the Birmingham District. It is borne out, however, by statistics which I have presented in this paper, showing how our Southern production has remained almost a constant, while in the Northern District production has rapidly increased. For the Southern merchant furnace to be as big a money maker and as prosperous as a Northern merchant furnace, it will have to have over

a period of years nearly the same average price for pig iron as the Northern furnace, and it is erroneous to think that Birmingham regulates, or ever will regulate the pig iron market of the world. It makes low prices on its pig iron because it has to make low prices in order to sell it in Northern territory, and the Southern furnaces will never prosper as they should until a market is developed for their output in the South; nor is there the slightest hope that steel is ever going to be made in this district so cheaply that it can be shipped to Pittsburgh and Chicago and return as much profit on the investment as money invested in iron manufactories in those districts. Our prosperity is dependent upon finding a market for our steel products in the South and upon export trade."

The Influence of the United States Steel Corporation.

A few years ago the United States Steel Corporation became interested in the Birmingham District, and since that time has spent many millions of dollars in rebuilding and developing the properties of one of its subsidiaries. Only recently it has completed for another one of its subsidiaries what is said to be one of the most modern nail and wire plants in this country. To my mind this is perhaps one of the most important developments that has ever taken place in this district, and it is destined to do more for its future welfare than any other one factor. This may sound a little bit strange coming from a competitor, but nevertheless I believe it to be true. I trust that just in this connection you will pardon a personal reference. In 1907 the writer asked the President of one of the Corporation's subsidiary companies what would be the policy of the corporation towards its competitors? He replied, "To live and let live" and that competitors would be treated fairly. This statement has been borne out in subsequent years, and I hope it will always be true. These officials seem to have had a broad and comprehensive view of the structure they wished to create, and have consequently avoided many complications that would have otherwise overtaken them.

A Wiser National Policy Needed.

Recent developments have emphasized the weakness of this country in its merchant marine, and while I know that a majority of our people have not taken kindly to a "ship subsidy," at the same time I fail to see how we can come into our own without some kind of government assistance. If we are to take advantage of the opportunities offered in the South American countries we must have vessels sailing from our Southern ports at regular intervals, and when we get these the cargoes will be waiting for them.

For many years past this country has had in effect a tariff which has, to some extent at least, protected its manufacturing industries until many of them have grown strong and no longer stand in need of this helping hand. Does it not seem strange, therefore, that just in the beginning of the era of industrial activity in the South, when this same helping hand is so badly needed here, that it should be, and by our own representatives too, so ruthlessly withdrawn? But many strange things have occurred before while this same party was in power and which, too, have been the undoing of it in subsequent years. (Applause.)

Note—In the above I have quoted somewhat at length from a paper written by Geo. G. Crawford, Esq., President of the Tennessee Coal, Iron & Railroad Co., in 1910, on the "Southern Iron Producing District," and also from papers by J. J. Porter, Esq., Metallurgical Engineer, of Staunton, Va., and E. C. Eckel, Esq., Mining Geologist, Washington, D. C.

MODERN DEVELOPMENT OF THE IRON AND STEEL INDUSTRY IN THE SOUTH

George W. Connors

President Connors-Weyman Steel Company, Birmingham, Ala.

This distinguished assemblage has come here from a national interest in the South, and in the Birmingham district, the heart of the South, a district rich beyond computing in the mineral properties locked in her vaults; and the South is glad of this opportunity to show her vast resources and submit the story of her progress, a development only curtailed by reason of the limited capital at her command.

The story of the wealth and variety of the minerals in this great section, wrought into finished products, was forcefully told by the Tennessee Company's exhibit at our State Fair. In raw materials there were huge blocks of coal, iron ore, limestone and dolomite, also by-product coke, basic and foundry pig iron. In finished products there were rails, boiler plate, rounds, squares, flats, concrete bars and other shapes, even high grade tool steel worth 50 cents per pound, all produced from raw materials assembled from within five miles of its works, the coal from a mine within the steel plant enclosure. This remarkable exhibit seemed the realized day dream of the early pioneer.

The South's Wonderful Growth.

Mr. Glenn's able paper has correctly told in detail of the marked development of the South's great resources from the earliest date to the present period. This discussion will, therefore, be confined to that time beginning with 1880.

During the last four census years, respectively, the South's percentages of the nation's total production were:

	Coal	Coke	Ore	Pig Iron
1880	10%	11.2%	10%	11.7%
1890	15	22	22	20
1900	20	28.5	17	19
1910	24	22.3	12.3	12.6

In 1880 the South produced 373,982 tons of coke. By 1913 this had grown to 8,169,428 tons, an increase of 2084 per cent. The South's total production during this period, 153,332,570 tons, was equal to 23.71 per cent. of all the coke made in the United States during that time. In 1880 the South produced of iron ore 702,515 tons, and in 1913 6,343,-218 tons, an increase of 802.9 per cent. Our total production during that time of 132,643,148 tons was 15.4 per cent. of this country's total. In 1880 the South produced 448,978 tons of pig iron. By 1913 this had grown to 3,285,957 tons, an increase of 631.9 per cent. In the 34 years the South produced 69,473,617 tons, or 15.3 per cent. of all that was produced in the United States during that time.*

While the past ten years shows little increase in our Southern pig iron production, this may be considered more of an advantage than otherwise. During the same period there was an increase of 98 per cent. in the steel produced, showing much greater home consumption of pig iron. This is a step in the right direction at last, though still only a beginning.

The five steel plants in the South are making a limited variety of finished products such as rails, merchant bar, boiler plate, plow steel, angles, channels and a few other small shapes. Some of them are making wire, wire nails, wire fencing, barbed wire, and are furnishing billets to rolling mills making hoops and cotton ties, light bands, etc. While this means much, it is evident there is ample room for many more such plants.

Resources of the Birmingham District.

Now let us see something of the extensive resources of the Birmingham district and what it has been doing in the way of development of its vast mineral wealth.

For a long time her pig iron was considered unfit for steel making and the more finished lines owing to its high silicon and phosphorus. Today her basic open-hearth steel is widely known, and the quality ranks second to none.

* Figures from *Manufacturers' Record.*

The accompanying table tells what has been accomplished.*

Years	Coal	Coke	Pig Iron	Steel
1900	8,394,275	2,110,837	1,184,337	66,076
1901	9,099,052	2,148,911	1,125,212	113,524
1902	10,354,570	2,552,246	1,472,211	176,252
1903	11,654,324	2,693,497	1,551,398	152,958
1904	11,262,046	2,340,219	1,453,573	196,623
1905	11,866,069	2,576,786	1,604,062	305,117
1906	13,107,963	3,217,068	1,674,848	320,327
1907	14,250,454	3,096,722	1,686,674	319,620
1908	11,604,593	2,335,602	1,397,014	341,336
1909	13,703,450	3,047,510	1,763,617	349,462
1910	16,111,462	3,231,399	1,939,147	529,684
1911	15,021,421	2,756,697	1,712,443	456,728
1912	16,100,600	2,881,861	1,833,658	716,300
1913	17,678,522	3,526,624	2,025,378	778,391
	180,208,801	38,515,979	22,523,572	4,822,398

These figures show a large increase since 1900 in coal, coke, pig iron and steel, nevertheless, they also emphasize the necessity of greater development in the finished lines. Too much of Birmingham's pig iron is still going to distant markets, requiring the absorption of heavy freights to compete with Northern iron; while the natural home market not only remains uncultivated, but is allowed to buy too much finished iron and steel from a distance, when by further development much of it could be cheaply made at home. Until this is done this district, as well as the South, will never prosper as it should.

Some Alabama Figures.

Alabama, which ranks second to Pennsylvania in coke making, produced 3,526,624 tons in 1913, valued at $10,-227,209, an average of $2.90 per ton at the ovens. "In the same year West Virginia produced 2,472,752 tons of coke, valued at $5,504,416, or an average of $2.23 a ton. The higher average price obtained in Alabama is due to the fact that most of Alabama coke has its market right at home, while West Virginia not only ships most of its coke to consumers in other States, but of 11,834,251 tons of its 1913 production of coal that was made into coke, 7,546,674 tons, or nearly 64 per cent. were carried to other States, princi-

* Figures from the Birmingham Chamber of Commerce.

pally Indiana, Illinois, Maryland and Ohio, to be used in their coke ovens." *

It is gratifying to note the advancement made in the Alabama cast iron pipe industry. Its enlarged plants with their increasing consumption of raw material makes it an important factor, adding greatly to the commerce and wealth of this section.

The day of wasteful extravagance is passing and each year finds the larger interests spending millions to conserve the mineral supply with which this State has been so lavishly endowed. The economy of the by-product coke ovens has wrought wonders in this direction.

Cement is being made here in large quantities from blast furnace slag. It will be interesting to know that the phosphorus which has hitherto been a detriment to the pig iron of this district, and removed from it in a slag made in the basic open-hearth furnace, which was worthless because of its low content of phosphorus, is now eliminated in the form of a slag of such high phosphoric acid content as to make a valuable fertilizer for our Southern crops.

The Coming of the United States Steel Corporation.

The year 1907, when the United States Steel Corporation acquired the Tennessee Company, marks the most important epoch in the development of the iron and steel industry of this section. Previous to that time, this Company had never been able to secure the necessary funds for its proper development. Since then large improvements have been made, costing many millions. The expenditure of this vast sum was wisely directed by the able hand of its President, who brought back to his native South knowledge, based upon wide experience, sufficient to cure past defects in plant and operation by applying more modern methods of progress and conservation.

Much credit is also due to the personnel of his able corps of picked men for what has since been accomplished by the Tennessee Company. This has brought much prosperity

* *Manufacturers' Record.*

to the South, and especially to this district, which is not in sympathy with the Government suit to separate the Tennessee Company from the United States Steel Corporation. If such an unwise decision should be made, it would be a colossal blow to this section of the South and would be made over its earnest protest. (Applause.)

To further develop the vast resources of the South requires greater capital than is at her command, as well as more men of the proper technical training coupled with the necessary experience and ability to construct along right lines. Practically as much depends upon the one as the other. That which has already taken place has been done mostly with outside or foreign capital. If this development continues as it should, every encouragement must be offered to obtain the necessary money from without its bounds. The South must then furnish the proper protection and be willing that a safe and reasonable return should be made on the investment and refrain in future from any unwise or unjust legislation.

In conclusion I desire to emphasize Mr. Glenn's reference to the harmful effect in withdrawing the much required protection to our Southern industries just at the time it was most needed. It is to be hoped that our representatives will realize fully the oppressive legislation to which we are subjected, and that a returning sense of justice will influence them to heed our remonstrances. Unfortunately the idle plants and unemployed thousands are mute tributes to this mistaken policy. The European war will be pointed to in defense but it came after the main blow had been dealt. (Applause.)

THE MODERN DEVELOPMENT OF THE IRON AND STEEL INDUSTRY IN THE SOUTH

M. P. Gentry Hillman

Carpenter & Hillman, Birmingham, Ala.

The admirable history you have had the pleasure of hearing precludes any idea of adding much that will be of interest. However, a short history of the modern development of the blast furnace practice of the Birmingham District may be an appropriate supplement; and with this idea in mind I have written the following epitome of the subject:

The scope of such a paper being necessarily limited, it seemed that a short history of the Ensley plant of the Tennessee Coal, Iron & Railroad Company from the beginning of its operation to the present time would give the clearest view of the modern development of the blast furnace practice of the Birmingham District. That no mention is made of the progress of the contiguous plants of the district is not to be understood as meaning they were not also improving their plants. The initiative of a large amount of progress belongs to them, and no one plant in the district can be said to have been first with all the improvements.

The questions of skilled labor and trained heads of departments were of the greatest importance when the development of the operation of the Ensley Furnaces was undertaken, and it is not surprising that several years elapsed before the organization had been perfected into a compact and smooth-running machine. New mines for the production of fluxing stone, ore and coal for this plant had to be opened and equipped, and from the beginning it was apparent that there was not enough money to purchase the proper equipment. This lack of funds became acute two years prior to the panic of 1893 and lasted until 1898. The stock of the company being known during this period as "the football of Wall Street," there were several changes of ownership, prejudicial to the good that would have devel-

oped had these changes not been made. The lack of money to purchase the proper equipment, the panic of 1893, and the several changes in ownership will present to you the main reasons why a district so gifted by nature for the manufacture of cheap iron produced for so many years such poor financial results.

The Original Ensley Furnaces.

The four Ensley furnaces as originally constructed in 1888 were all alike, each furnace being 80′ high, 30′ from hearth to stock line, diameter of hearth 11′, diameter of bosh 20′, diameter stock line 15′ 3″, number of tuyeres 8. Each had three Weimer blowing engines, 42″ steam cylinders, 84″ blowing cylinders and 54″ stroke, four 3-pass Gordon stoves with 23,900 sq. ft. heating surface, and vertical hoists, the filling being done by hand. Nearly, if not all, of the ore and limestone was broken in the stock house by hand. There were no bins, the coke cars were placed in the rear of the stock house, and the coke was forked from the cars to the coke buggies. There was no laboratory and the chemical handling of the burden was superficial. The quality of the coke, all bee-hive, was poor, due to high ash and improper preparation in the oven. It also possessed the marked disqualification of being very irregular in quality. Large lumps of fluxing stone and ore were charged into the furnace and "limesets" were common. The extreme height of the boshes, no chemical supervision of the burden, the large ore and fluxing stone, and the quality of coke added together, made a furnaceman's life, to say the least, anything but pleasant. The output per furnace ranged from 100 to 130 tons of foundry iron. The blast, piston displacement, varied between 28,000 and 35,000 cu. ft. per minute. Foundry iron was produced, silicon in No. 2 Foundry being held as near 2.50 per cent. as possible. The ores were from Red Mountain and at that time the outcrop, that part of the vein under light cover and from which the limestone had been leached, constituted a part of the burden. The per cent. of hard ore, or the ore from which the limestone had not been leached, was three-fourths,

and the soft ore, the leached ore, one-fourth. Occasionally limonite, known as brown ore, was used, but the supply was irregular and cannot be said to have been a regular part of the burden.

In 1891 a laboratory was constructed and chemical supervision of the raw material inaugurated. Better beehive oven management was obtained and the quality of the coke improved, though the ash was still high and the quality irregular. These improvements increased the output per furnace to about 150 tons. In 1892 the first coal washer was installed and this marked the beginning of the radical increase in furnace output. A coke of uniform analysis and of good quality was furnished and the results were highly satisfactory. Coincident with the introduction of the coke from washed coal came a change in furnace lines. The hearth diameter was increased, the bosh was lowered several feet and the diameter of the stock line decreased. Crushers were installed at the ore mines and quarries and while the crushing was still imperfect, the largest lump passing through an 8″ ring, it was a step in the right direction. The output increased to an average of 200 tons per furnace. The improvements just mentioned called for an increase in air volume which produced increased pressure; and it soon developed that the blowing cylinders with wooden piston packing and leather-faced valves were out of date. The continual bursting of cold-blast mains and the shells of the Gordon hot-blast stoves also demonstrated that these parts of the plant had seen their day, and it was also shown that the heating surface of the stoves was not sufficient for the increased volume of air. But there was no money, and the plant was left to fight its way with these handicaps.

The Production of Basic Pig Iron.

With the exception of an increase in boiler power and improvements in furnace lines, the plant made no further progress until 1898, which year marked the advent of basic iron at Ensley, increase in number of tuyeres and by-product coke. As the best of the soft ore, the outcrop of Red

Mountain, was getting scarce, brown ore was introduced in its place and the maximum quantity of this ore was used in the furnace burdens from 1894 to 1900. On account of the increasing cost of brown ore and deterioration in quality the amount used gradually became less, and as very satisfactory results were obtained by judicious mixtures of the hard ores of Red Mountain, brown ore ceased to be an important factor of the furnace burden. And to-day the very best results being achieved are obtained from the use of all hard red ore. It is highly probable that very little, if any, brown ore will in the future be used in the immediate Birmingham district. The ratio of bases to acids of the slags when on foundry was about .8 to 1, and when on basic iron about 1 to 1. The large slag volume, about a ton of slag to the ton of iron, made the problem of control of sulphur in the iron an easy one as the point of saturation of the slag by this metalloid was rarely, if ever, reached. It may be of interest to relate here that No. 2 Furnace was equipped with 24 tuyeres. The attempt to use them, however, was disastrous, and 12 were blanked; the furnace making a very satisfactory blast with the remaining 12 tuyeres. The use of 12 and 16 tuyeres was of great value, as the reduction in blast pressure was favorable to the weak cold-blast mains and stoves as well as the antiquated blowing engines. The company having no money to build ovens, made a trade with the Semet-Solvay Company in the same year, and 60 ovens, to which an addition was subsequently made, were built behind the stock house. The beginning of the use of this coke was the beginning of serious trouble with the furnaces, and the many irregularities made such an indelible impression on the minds of those connected with the operations that it has been difficult to remove these prejudices. However, the Semet-Solvay Company has conquered the problems it encountered and is to-day producing a superior coke, the same being true of the Koppers plant of the Tennessee Company at Fairfield. At present all the furnaces of this company are using by-product coke.

In July, 1895, the first basic iron made in the Birmingham district was produced by No. 2 Alice Furnace, and the

successful manufacture of this iron paved the way for a steel plant. As above stated, the Ensley plant commenced the manufacture of basic iron in 1898, and since the beginning of operation of the steel plant, November, 1899, with intervals of short duration on foundry, has steadily produced this grade. The boom in pig iron in 1899 found the Tennessee Company anxious to increase its producing capacity, but, as usual, the company was without funds to construct a new furnace. Doing the best they could under the circumstances they purchased an old furnace in Florence, Ala., and together with what material they secured from another old furnace they owned at Cowan, Tenn., constructed No. 5. This furnace was smaller than the other four and was torn down in 1905 to be supplanted by the present No. 5. The plant continued to operate with the equipment until 1903, when 12 vertical Mesta blowing engines were purchased and installed. This afforded great relief in so far as cost of maintenance and steam consumption were concerned, but their full efficiency was minimized by the weak cold-blast mains and stove shells, the blast pressure being limited to 13 pounds. In the same year a much-needed water purification plant was installed.

The period from 1902 to 1905 marks a pause in any progress in furnace output. The three chief causes were the rehabilitation of the equipment of the ore mines and rock quarries, pending completion of which improvements inferior and poorly prepared ore and flux were shipped, the strike of the coal miners and the decision of the management to quit washing coal for the manufacture of coke.

In April, 1905, No. 6 Furnace, the first modern furnace at Ensley, was blown in. The furnace was 85′ high, hearth to bosh line 20′, diameter bosh 20′ 9″, diameter hearth 14′, diameter stock line 14′, double skip, Brown revolving top, four Massick & Crookes stoves, 46,000 sq. ft. heating surface, vertical Mesta engines, and 12 tuyeres. From the first the operations were successful and demonstrated that a furnace of this size was a practical unit in the Birmingham District. Handicapped with a large per cent. of coke made from unwashed coal, she averaged 330 tons, and was the

antecedent of the splendid furnaces which now constitute the plant. In the fall of the same year No. 5 was torn down and in 1906 a new furnace in her place was blown in, being practically a duplicate of No. 6.

Developments Since 1907.

In 1907, No. 4 furnace was dismantled and a furnace slightly larger than Nos. 5 and 6 was erected, the diameter of the bosh being 21′ 9″, of the hearth 14′ 6″. From 1908 to 1911, Nos. 3, 2 and 1 were dismantled, and three furnaces larger than Nos. 6, 5 and 4 were constructed, the bosh diameter being increased to 22′ 6″ and the hearth and stock line to 16′. As a matter of interest it may be well to mention that No. 1 is a thin lined furnace. The work of these three furnaces has been superior to any results so far obtained in the South, one of them having made over 600,000 tons of iron and is still in good condition. The average output of the three large furnaces is about 400 tons per day.

The rapid development of the plant to its present state of efficiency and working out the proper preparation of raw material was begun in 1908 and has recently been consummated. All the coal from which coke is made is now washed, thus insuring fuel of low ash and uniform quality, and the ores and fluxing stone are properly crushed. The question of inadequate supply of water had from the beginning been a serious handicap to the plant. The completion of the splendid improvement at Edgewater in 1911 affords the plant ample supply of water and has made possible the installation of an efficient condensing plant by which thousands of horsepower, heretofore wasted, have been put into harness. It is also of interest to note that turbo-blowers have been introduced and are being successfully operated.

One cannot view the history of this plant without regretting that it ran so many years without the capital and organization necessary to keep it in the front rank of development. It is to be hoped that sufficient capital will be provided from the start for resources yet to be developed, and that stability of ownership will guarantee an operating organization which is not subject to changes, an organiza-

tion that will reach its highest efficiency by years of continuous service.

I know of no greater pleasure than to be able to say to you that largely through results now being secured at this plant, the great natural resources of the Birmingham District have at last come into their own, and if left in the hands of capital and competent organization, will ever prove to be a part of the industrial success of the country.

SOUTHERN FOUNDRY PIG IRON

JAMES W. MCQUEEN

Vice President, Sloss-Sheffield Steel and Iron Company,
Birmingham, Ala.

To give a Birmingham man this subject, with no instructions as to his limitations, is something no one familiar with Birmingham men, and at the same time mindful of the feelings of other members, should dare to do.

There is much that could be said; but as the time is limited, it shall be my object to spare you as much as possible.

I shall waste no time in picturing for you the wonderful growth of Birmingham, from the time it was discovered that Red Mountain was almost a solid block of iron ore, on down to the new Union Depot, our latest sky scrapers, or the Tutwiler Hotel.

To deny myself the pleasure of referring to these and the many achievements of this district, requires a large amount of self-restraint; and the fact that I have this is about the only qualification I possess, and is, no doubt, one of the reasons I was selected to read this paper.

I believe after your visit here you will accept as an undisputed fact the statement that all of the vast treasures of mineral wealth which you have read so much about, are at our very doors. A great deal of it remains in the raw state; and, unfortunately, no inconsiderable quantity of it is in its semi-manufactured form, which we would far rather see today at our neighbors' doors, even in their yards.

HISTORICAL.

Iron is the most abundant and useful of metals and one of the greatest staples of commerce and industry. It is found only rarely in the pure state. In such cases it might literally be termed a "heaven-sent blessing," its occurrence being limited to meteorites which fall upon the earth from

ærial regions. But in some form it can be found almost everywhere on earth. The extent to which it is used will mark the progress of civilization, and it is commonly spoken of as the barometer of trade.

We find the first furnace in America was a bloomery erected in Virginia in 1619, and the first blast furnace with forced draft was built in Virginia in 1714, from which, no doubt, was produced the first Southern foundry iron.

In Alabama the first furnace of which we have any record was a small and crude furnace built on Clear Creek, in Franklin County, in 1818, on lands now owned by the Sloss-Sheffield Steel & Iron Company, and in the locality where its practically inexhaustible territory of brown hematite ore is now being worked, which ore yields a little better than 50 per cent. in actual furnace practice.

While I do not vouch for the story, once in crossing this territory with some of our Directors, Jim Sargent, one of the mine foremen, pointed out to us a spot where he vowed horses were shod before the war with shoes made from the ore as it came from the bank.

Southern foundry iron was never made in any quantity in Alabama until the early seventies, the records showing as follows:

1872	11,000	tons
1882	100,700	"
1892	915,300	"
1902	1,472,200	"
1912	1,863,000	"
1913	2,058,000	"

The figures for the last decade include considerable tonnage of basic iron, which I have not been able to separate and deduct from totals given above.

Southern Foundry pig iron, in the trade acceptance of the term, means foundry iron produced in Alabama, Georgia, Tennessee and Kentucky. In these States there are, all told, 82 stacks or furnaces. A number of the stacks cannot be considered as "active," on account of their small size and

antiquated equipment, thus preventing competition with the more modern furnaces. This class of furnace will probably never be put into blast again.

Some Characteristics of Southern Foundry Pig Iron.

Southern Foundry pig iron has many characteristics entirely different from northern iron. The first important difference is due to the ores, most of our Southern ores having self-fluxing qualities and being chemically different from the northern ores. The main chemical difference is in the phosphorus, which is reflected in the resulting pig iron. The Northern producers, in extreme northern markets, have found it profitable to imitate Southern iron in phosphorus contents, because of the demand for this element in certain lines of work.

Not only are the silicon and phosphorus of Southern iron appreciated by practical melters, but its mixture with northern iron has many converts. It is known to be valuable in neutralizing or balancing chemical elements; there are also inherent characteristics in its composition which produce results in practical tests which confuse the strictly chemical mixer. This is logical, as it is known that 92 to 93 per cent. of all pig iron is metallic iron, so the alloys of carbon, silicon, phosphorus, sulphur and manganese represent only 7 or 8 per cent. of the total weight. While, of course, the chemical elements have their influence on the action of iron in the cupola, there are physical characteristics in Southern foundry pig iron not explainable by the chemist.

In a lengthy argument I once overheard between a chemist and a foundryman, the latter, being pressed for a clearer explanation, said he could only state that it was due to the virtue possessed by Southern foundry iron; and we all know what a valuable asset that is. Practical foundrymen have satisfied themselves that the use of the Southern product has demonstrated the following facts:

1. Southern foundry iron makes a more fluid iron and sharper, cleaner castings.

2. It will produce a softer casting, with the same silicon content as northern iron.

3. There is less internal shrinkage.

4. There is less contraction, and, as a consequence, the resulting casting is nearer the size of the mould than when northern iron is used exclusively.

5. It will produce a finer grained casting without losing softness.

6. There is almost no skin or hair edge noticeable in the broken casting, while the northern irons chill more rapidly and produce the harder surface.

As these results are becoming more widely known, Southern foundry iron is gaining in value to the melter.

An instance of one experimental test may be of interest. In a certain large foundry making machine tool castings, the chemist advocated a phosphorus content in the mixture of about .36, which permitted the use of only 10 per cent. of Southern iron with some reputable brands of Northern iron with phosphorus down to about .16 to .25. The foundry superintendent, a practical man, contended that better machine castings could be made with a mixture of Southern iron with phosphorus about .90. To confirm this contention, two square test bars were made, one by the chemist showing phosphorus .36; another by the foundry superintendent, showing phosphorus .89. The silicon was about 2 per cent. in each case. These test bars were put on a planer, locked end to end and a ¼-inch cut made from one side, a ½-inch cut from the second side, 1 inch cut from the third side, and 1½-inch cut from the fourth side. The cuttings and the bars showing the grain were submitted to a committee of machine shop experts for determination as to which was the better casting. The committee, having no knowledge as to the analysis of either test bar, or which bar was the one made by the practical man and which made by the chemist, were unanimous in selecting the .89 phosphorus bar as the better casting. This contained a large percentage of Southern iron, and the chemist was convinced that Southern iron, with its phosphorus properly used, was a beneficial element.

New Uses and New Markets.

When automobile cylinders became a problem for the American foundrymen to solve, pieces of cylinders made by the best European makers were analyzed, and it was found that the best French cylinders showed 1.33 phosphorus, the English 1.10 phosphorus, while American makers were using only .60 phosphorus; and some of the high-priced car builders were buying cylinder castings from France.

Much can be said in favor of buying iron by analysis; but on the other hand, there are many causes affecting the success of such practice other than the chemical elements of the iron charged into the cupola. It very often happens that a foundry will buy iron on analysis, and when it comes to the point of using it the iron and other materials are not even weighed but guessed at by a few laboring men. Again, very often they charge miscellaneous scrap, the analysis of which they know nothing about. In such cases the blame cannot in justice be placed on the pig iron.

As I have endeavored to make clear to you, Southern foundry pig has many characteristics entirely different from any other. During the early days of this industry in the south, it stayed very close at home, occasionally venturing on a trip up the river, but never very far. Later, during the eighties, when the industry began to expand—especially in the Birmingham District—the pig acquired roaming habits; it would not stay at home. It made its way up north, all along the great Lakes, into Canada, all over New England, out to the Pacific Coast, and down into Mexico. Becoming a veritable tramp, it frequently found its way on board tramp steamers, visited many foreign countries, and entered most European ports, and those of Japan, China, Australia and Africa. Wherever it went, it brought the joy and sunshine of its native land. To the northern laborer, sweating and breaking his back on Lake Superior charcoal pig, it was a veritable godsend. It yielded easily to the blows of the sledge. His employer, the foundryman, was grateful for its help. Its smooth and winning way added new lustre to the stoves it went to make, and its cheapness enabled the

stove maker to reduce his price and sell more. It also enabled the farmer to buy more and better machinery.

Southern pig has always been a friend to everyone, and no satisfactory substitute for it has ever been found. There are people who claim that Southern foundry pig will never exert the power it once had in some markets. Perhaps so, but other markets are growing all the while, and this in spite of the fact that we have been hearing the doom of Southern pig predicted for twenty years. We have weathered far worse storms than this, and we have seen the tide turn in our favor again and again. We believe the time is not far distant when the demand for American iron and steel products of all kinds will tax the capacity of our plants; and when that time comes, Southern foundry pig will not be the "little pig that stayed at home," but it will go to market every day. (Applause.)

Here it was moved, seconded and carried that the discussion by Mr. Lemoine, to be furnished later, be printed as a part of the proceedings.

SOUTHERN FOUNDRY PIG IRON

Luis R. Lemoine

President, United States Cast Iron Pipe and Foundry Company, Philadelphia, Pa.

Southern foundry pig iron suggests the "Sunny South" with its warm-hearted and gracious people. Incidentally, Birmingham, the pig iron center of the South, with its great industries and store of mineral wealth, its wonderful growth and promising future, is the magnet which will continue to draw many who work in iron and steel, and cotton; until there shall be here a city which shall rival the manufacturing centers of the North.

Characteristics of Southern Iron.

In his very interesting paper, Mr. McQueen summarized the characteristics of Southern foundry pig iron, and told you how this iron finds its way in ever-increasing quantities throughout nearly all this broad land, and now and again into foreign countries. And certainly, for the purposes he mentions, where fluid irons, low in sulphur, are required, there is none better. However, as he also suggests, some northern irons with like qualities are available; and again, some which afford greater strength in the casting have even less shrinkage. Foundrymen, no doubt, could wish that southern foundry pig iron embodied those mystic qualities which Mr. McQueen implies; or if perchance it does, they could lay hold of them as evaporators of mix troubles. It is doubtful, however, if there are physical or other characteristics in foundry iron which for all practical purposes cannot be determined in the laboratory. Increasingly difficult specifications for castings and the greater necessity for reducing shop losses on large outputs compel laboratory guidance. This southern open fluid iron, well adapted to the lighter class of castings, will not alone make a suitable mix for heavier castings in which often greater tensile and

transverse strength is required. Hence, where comparatively large tonnages are involved for use in castings often covering a rather wide range in designs and weights, foundrymen are, I believe, rapidly getting away from fracture grading as a guide to mixtures. On the other hand, these high silicon, high phosphorus southern foundry irons are good scrap carriers and as such are much to be desired in the jobbing foundry trade, especially where comparatively small melts and the lighter range of castings are the rule. In the aggregate a considerable tonnage is thus used and often the selection by fracture is alone possible.

Better Methods of Grading.

I quite appreciate Mr. McQueen's contention to the effect that sand cast southern foundry pig iron is a valuable asset. Strange as it may seem, however, we frequently prefer to base our mixtures on machine cast; and it is our rule to check fracture grading in the laboratory. We have thus often found the reported fracture grading a misnomer and now and again have had to rehandle iron to other locations in the foundry yard in that it was found unsuited for the mix it would have entered had the fracture grading correctly represented the approximate analysis. May I be permitted to suggest that from the foundry standpoint, if there is any one factor that would improve southern foundry pig iron, and northern iron for that matter, it would be through greater uniformity. Undoubtedly, all furnace men have constantly before them quality of product, but have they gone as far as they may in helping the foundrymen who must contend with so many variables. It would help much if foundrymen could always depend on having each cast shipped separately, and the foundry advised in advance as to how it falls within the specified limits as to silicon, sulphur, phosphorus and manganese, and if practicable, as to carbons. Thus, on arrival, the iron could be better placed on the foundry yard with reference to the mixes of which it should properly form a part. Perhaps the day will come when all modern furnace plants, as one or more have already, will introduce mixers or their equivalent, so

that each cast may be the more homogeneous and its character the more definitely known. The more nearly the foundryman knows the character of the iron he is using, the more accurately can he make his mix with a consequent lessening of loss from iron troubles in the foundry.

THE REAL INTERESTS OF THE PEOPLE.

There is an economic side to this subject, affecting not only the "Sunny South" but indirectly the entire country. Southern foundry pig iron is largely, if not entirely, the product of corporations. Without attempting to discuss the mistaken popular aversion to "big business" regarding which, fortunately in some directions there is an evident tendency to saner views, it may not be amiss to suggest to the producers of iron and steel—south and north—the importance of constantly pointing out to employees and their community, how interdependent are the real interests of the people, the employees, and these corporations; that as the latter prosper, so must benefit their stockholders, their employees, and through both, the community as a whole; that consequently, the people through their representatives should foster these corporations and help them to build up their business so long as it is conducted in a way that is not detrimental to the public. Let us all right-about-face; and, taking courage, strive to lead the way in a spirit of warm-hearted helpfulness to better things. This is essentially a time to look onward and upward.

SOUTHERN FOUNDRY PIG IRON

PASCHAL G. SHOOK

President, Chamber of Commerce, Birmingham, Alabama

The excellent paper read by Mr. McQueen, giving an historical resume of Southern Foundry Pig Iron from the early days of the industry down to the present time, clearly demonstrates that the selection of the writer of the principal paper on this subject was a wise one.

Mr. McQueen ought to be, and is, in a position to speak advisedly on this subject. For a number of years he has been Vice-President of the Sloss-Sheffield Steel and Iron Company, the largest producer of Southern foundry pig iron for the open market, and in that capacity has had charge of all sales made by his company. He has sold more Southern foundry pig iron than any other man living or dead, and is deservedly credited with being the best pig iron salesman in the United States.

As evidence of his qualifications in this direction, and of the fact that he possesses unusual qualities of salesmanship, it will be noted that in his paper which you have just heard, he points out with striking and convincing clearness the fact that high phosphorus Southern foundry pig iron is admirably adapted to the manufacture of automobile cylinders and other important machinery castings requiring great strength, and at the same time is peculiarly suited for stove castings on account of the quality of fluidity afforded by the comparatively high percentage of phosphorus contained in our Southern irons. In other words, in the case of automobile cylinders, the added "strength" in phosphorus is a material factor bearing upon the adaptability of our metal for that purpose; and in the case of stove castings, the desirable quality of fluidity, derived from phosphorus, is one that appeals to the stove maker. So that it becomes immediately apparent that this despised element has its

advantages which are available alike to the automobile manufacturer and to the stove maker.

Develop the Home Market.

While not as optimistic as Mr. McQueen as to the future of Southern foundry pig iron, I hold the opinion that the difficulties and obstacles in the way of future expansion are not unsurmountable, and that in overcoming these difficulties we should pursue a program of home development which will result vastly more to the benefit of the South and to the iron and steel industry than would follow continued effort to hold and enlarge the markets for Southern foundry iron.

Pig iron being essentially a raw material, it is very desirable that our efforts should be directed along the line of converting this raw material into finished product and offering it as such to the consumer. We cannot hope to reach any large measure of success and development as an iron and steel center until this is done. To some extent we have progressed in that direction. A few of our larger iron and steel concerns are now manufacturing steel on a large scale, and it is believed that they have plans for increasing their production of steel and converting the same into finished articles of daily use, and coincidently curtailing their sales of pig iron.

Practically all of our active Southern furnace companies have large reserve raw material supplies, both coal and ore. These supplies were required in the early days as a basis for bond issues as a rule. But in many cases they have proven a burden rather than an advantage, because the present day cost is necessarily taxed with the carrying charges of enormously extensive and valuable raw material deposits which cannot be utilized for many years to come. This situation can, and I believe will, be relieved to a great extent by the building of additional furnaces to consume these raw materials, not for the purpose of marketing pig iron but for manufacturing steel going into articles of use such as can be sold in the South or in territory that can be reached from this section.

Influence of the Iron Industry.

The palmy days of the manufacturer of Southern foundry pig iron were those embraced in the period of about twenty years from 1880 to 1900. Even that period was not characterized by any large profit to the manufacturer, but there was a demand for his product from many and varied sources. During this period there were fluctuations in the selling price, which resulted in fat and lean years. It may safely be asserted that the average selling price over the entire period did not, as a rule, yield to the manufacturer any profit in excess of the requirements of interest on funded and floating debt, both of which classes of indebtedness the Southern foundry pig iron manufacturer has unceasingly and unremittingly been compelled to carry from the days of the earliest development down to the present moment. The impoverished and destitute condition of the South following the Civil War precluded the possibility of financing industrial developments of any character on a large scale without financial assistance from the North and East, the result being that in the majority of cases the construction of blast furnaces and the opening of mines and quarries for supplying raw materials was accomplished with money secured by the sale of bonds, as no local capital was available for such development.

The period mentioned covered the development of the iron industry in this country in the sense that during that period was witnessed the greatest activity and development in the manufacture of gray iron castings of all kinds, such as the general foundry trade supplied, and also iron bars rolled from the product of the puddling furnace. In those days a very large percentage of the output of Southern furnaces was mill grades sold for puddling purposes. There were, then, two large outlets for Southern iron, namely, the foundry requirements for all classes of castings, and the mill requirements for rolled bars. So extensive was the mill trade that there were in the early days of the industry in the South, grades established known as mill grades, No. 1 and No. 2 mill iron, which have long since been abandoned.

In addition to these mill grades, other low grades such as gray forge, mottled and white iron, were sold in very large quantities for puddling purposes.

The decline of the iron age was rapid and marked with the rise of the steel age, which resulted in the practical abandonment of rolled iron products, cutting off a very important consumer of Southern iron, and also in the enormously increased use of steel castings as a substitute for iron castings, thus tremendously curtailing the demand for foundry iron for cupola purposes. The decline in the use of iron rolled products and iron castings is too well known to the members of this Institute to call for any elaborate discussion here. It is well known that in the last fifteen years the change from iron to steel has been rapid and far-reaching, and that this revolution has had a more pronounced influence on the Southern foundry pig iron trade than any other one factor.

Some trade has come to the Southern furnaces as a result of this change, for basic iron for steel making, for both steel castings and ingot steel; but the manufacture of basic iron in the South, aside from that used in the South, has not been extensive.

Importance of the Cast Iron Pipe Industry.

Broadly speaking, the market for Southern foundry pig iron has narrowed to cast iron pipe, both soil pipe and pressure pipe, radiators, and a very limited number of other commodities. But for the cast iron pipe demand, I do not believe there would be a furnace in operation to-day on foundry iron in the South.

Of course it is a well-known fact that the Southern furnaces have always been handicapped by the distance to market, resulting in high freight rates to the large consuming centers. With the exception of the large pipe shops the demand for Southern foundry pig iron in the South is limited.

While little that I have said up to this time is favorable to the Southern foundry iron industry, I am not a pessimist and I believe, as already indicated, that the future in this

district and in the South for the manufacture of iron is very bright. On account of the conditions mentioned, however, we will be compelled to manufacture in the South such finished products as can be sold in the territory more advantageously reached from this center, or in neutral territory, also for export; thus consuming our iron at home instead of undertaking to market raw material. This is the salvation of the industry. The Southern iron makers realized the necessity for such action years ago, and as a consequence the Ensley Steel Works was erected in 1898–99. Since that time practically all the iron made at the Ensley Furnaces has been taken off the market as pig iron.

The Development of Steel Making.

The first basic iron made in the South was made at the Alice Furnace of the Tennessee Coal, Iron and Railroad Company in 1895, and sales of basic iron from that furnace, as well as the Ensley furnaces of the Tennessee Company have been made in recent years. Before it was known that basic iron could be successfully manufactured in the blast furnace, various attempts were made to treat the iron with the view primarily of desiliconizing. Immediately prior to the making of the first basic iron at the Alice Furnace, extensive experiments were made at a small basic open hearth furnace at North Birmingham under the supervision of Mr. Benjamin Talbot, who undertook to demonstrate the practical value of his process for desiliconizing blast furnace metal by passing it through a bath of basic open hearth slag. The operation was successful, but it was found to be unnecessary when it was demonstrated that low silicon, low sulphur iron within the limitations of standard specifications could be manufactured in the blast furnace.

Concluding, I offer the suggestion that the highest and best results, the most permanent and lasting benefits, will accrue to this great iron and steel district if the efforts of our iron manufacturers are directed towards increasing the production of basic iron and its conversion into steel in all of its finished forms, instead of undertaking to push the manufacture and sale of Southern foundry pig iron.

Adjournment of Afternoon Session.

The Chairman (Mr. Willis L. King, Vice-President): As indicated by the program, all the papers read during the forenoon and afternoon sessions are now open for informal discussion under the five-minute rule. (After a pause) It seems that no one cares to offer any further discussion of the papers, and we will now have some announcements from the secretary.

Mr. McCleary made sundry announcements relative to the meeting in the evening and the proceedings of the following day.

The Chairman: The meeting stands adjourned until seven o'clock this evening.

EVENING SESSION

After the dinner had been partaken of and the Secretary of the Institute had made sundry announcements, Judge Gary, President of the Institute, acting as Toastmaster, said:

I take pleasure in reading to the Institute this telegram just received from the Chamber of Commerce of the City of Chattanooga, Tennessee:

CHATTANOOGA, TENN., Oct. 29, 1914.

JUDGE E. H. GARY,
Tutwiler Hotel, Birmingham, Ala.

Chattanooga once more invites members of Institute spend Saturday and Sunday here. Please call attention that Chattanooga's importance as tourist, historic and industrial center is best evidenced by fact that railroad tickets provide stop-over privileges at Chattanooga. Those coming in parties will be provided with private automobiles if we are advised in advance of number and arrival. Will appreciate courtesy if you will read at meeting, so that all understand.

CHATTANOOGA CHAMBER OF COMMERCE,
PAUL J. KRUESI, *President*,
LEWIS BURKE, *Chairman Entertainment Committee*.

PRESIDENT GARY: It is to be hoped that a good many here will find it convenient to stop over at Chattanooga, and you will be well rewarded.

Quite a long program has been made up for the evening, and therefore, with one exception, it will be necessary to have the addresses very short. When you are called on to speak, please remember that if you talk too long the gavel may call you to your seat. That will be absolutely necessary. Also, in view of the fact that the time is limited, the introductions will be very brief, probably nothing more than an announcement.

There is one exception to the time limit. You will remember that the address that Mr. Bowron was expected to deliver this afternoon on the subject of The History of the Iron and Steel Industry in the South was postponed

until this evening. This subject is so large that it will be impossible for Mr. Bowron to cover it to his satisfaction during the time available. The paper which he has prepared would consume at least fifty minutes if he were to read it all, and he has kindly consented to occupy only thirty minutes, which is very short for the subject.

I have great pleasure in introducing our old friend, Mr. James Bowron. (Applause.)

MR. BOWRON: I am afraid of immediate expulsion from the ranks of the order if I were guilty of *lese-majesty*, so I will not speak ill of dignitaries. Otherwise, I would be disposed to complain of Mr. Farrell for likening me unto a two-stage compressor, and assuming that I could compress into the limits of a paper a history of the development of the metallurgical industries of the South. And then I would complain further of our honorable secretary, who seems to think that I am a condenser and can reduce a fifty-minute paper into fifteen. So now, considering the good times that the members have been having and the fact that some of them have reached almost the point of intellectual (only) saturation (laughter), it would not be at all out of the way if I were to ask the Judge if he is really as benevolent as the reporters make him out to be, and whether he would not consent to allow this paper to be published in the proceedings, and distributed in pamphlet form without being read.

JUDGE GARY: I do not think we would be satisfied with that, Mr. Bowron.

MR. BOWRON: Well, I am in the hands of the Court. All I can say, Judge, is "Pity the sorrows of an old man." You introduced me as an old man, and if you turn me loose, the way I am accustomed to be—for I have not read a paper in public for fifty years, being accustomed to say what the spirit moves me to say—if I was turned loose without fear of censorship at 30 Church Street, I could talk red-hot off the bat, like one of John A. Penton's editorials,

and I could go my friend, T. K. Glenn, one better on this thing, and then start out and express my appreciation of the exuberant prosperity, which I am delighted to learn from the newspapers has accumulated in our favor, as the result of the tariff legislation, the mercantile marine inactivity, and the watchful waiting of the Interstate Commerce Committee. (Laughter and applause.)

I will tell you all, I will make you a speech any time you want one, and as far as that goes, I won't mince words about it either, because I think—there are no cowans and eavesdroppers now listening to us—I think it is sometimes all right to take it lying down, but sometimes when you have had fifteen years of persecution, I think that common humanity would justify a man in hitting back.

Now, Judge, I will pitch in, and when I hear the gavel sound, I will light a cigar.

Mr. Bowron then read portions of his paper, the full text of which follows:

THE HISTORY OF THE IRON AND STEEL INDUSTRY IN THE SOUTH

James Bowron

President, Gulf States Steel Company, Birmingham, Ala.

This subject has been treated by many writers, J. M. Swank, W. B. Phillips, E. A. Smith, E. F. Burchard, and others, and Miss Armes, of Birmingham, has published an ambitious volume on "The Story of Coal and Iron in Alabama." I can only present an outline gathered from these authorities, to whom the inquirer is hereby respectfully referred. To some slight extent, perchance, I may enrich the outline thus presented with some coloring of personal reminiscence.

At the outset, my difficulty is to define "The South." Politically and historically, it should embrace the states south of the Mason and Dixon's line and east of the Mississippi, but metallurgically, we may dismiss from that category the states of Florida, Mississippi and Louisiana.

Again, the definition of the South may vary chronologically, for the metallurgical South of the ante-bellum period was much more extensive than the metallurgical South of to-day.

Before the war there was no iron and steel industry in the South based upon the manufacture of iron with mineral fuel. The records point to the location throughout the Southern States of small charcoal furnaces to which bloomaries were frequently attached.* These charcoal furnaces were sometimes blown from one tuyere with wooden blowing tubs operated by water wheels. Some of these furnaces produced only one or two tons per day and the iron was largely worked up by local blacksmiths into horseshoes, wagon tires and harrow teeth. In East Tennessee, bar iron became a local currency and was considered as valuable a medium of exchange at the local stores as eggs and ginseng are to-day. It is even chronicled that preach-

*Swank, p. 297 et seq.

ers were once paid in bar iron, but this statement may be *ironical.* These water-blown and water-operated forges were irreverently called "thundergust" forges. In those days there were no railroads and no macadamized roads, and the early settlers had to be self-dependent and work out their own salvation in peace and war against somber forests, rugged mountains, and stealthy unrelenting Indians, with the iron of their own production. A community had to make its own iron as it had also to spin and weave its own clothing.

Beginnings of the Industry.

For such crude methods only the rich and easily smelted limonites were available. These prevail in a broad belt paralleling the Alleghany Mountains and their subsidiary ridges through Virginia, East and Middle Tennessee, Northwest Georgia and Northern Alabama. In Virginia and Western North Carolina this belt of ores appears in a more massive form as fissure veins, and maintains the familiar condition of scattered gravelly deposits through the remaining states. Eminently treacherous as to continuity, they are more so as to analysis, and we have personally drawn samples over one field varying from .1 to .6 in phosphorus. The ease with which these brown ores could be smelted made them, however, attractive for the purpose, and the density of forests afforded a ready supply of charcoal fuel.

The industry appears to have crept southwestwardly with the gradual spread of population. In 1722 a furnace was started in Maryland, near Chesapeake Bay, to utilize the ore on the property of George Washington's father; but we read that the English manager on arrival investigated the ore available, and could not find more "than will serve for one blast, if that." Many of the laborers seem to have been English convicts. In 1725 they appeared to be making progress, for they planned to put the forge on double shift so that it might work up to eight tons per week! A part of this furnace was still standing in 1840. In Virginia we learn* that about 1716 some Germans came

*Swank, p. 259.

over under the auspices of Queen Anne "to make wine and help in the iron business." Some superintendents of iron and steel works in this day and generation will be interested to learn how and when began the apparent affinity between iron workers and potable beverages. The first blast furnace located at Fredericksburg went out of blast because of the failure of sufficient corn to support the oxen who hauled away the product. The furnace made 20 tons per week. The blowing engines, or bellows, cost $500.00, and one of the ore mines was from fifteen to twenty feet in depth.

In North Carolina we read of a furnace built in 1780, which was in operation down to 1873, and in South Carolina 1787 appears of record. The earliest furnace mentioned in Georgia was in 1832, and in Alabama in 1818, near Russellville, in what is now Franklin County. The plant was called Cedar Creek, being from 25 to 30 feet in diameter at the base, and narrowing into a smoke stack at the height of about 25 feet. This was operated by water power.

It is recorded that the farmers were glad to give the boulders of iron away to get them out of their way so that they might till their fields more easily. The fuel used was charcoal made from thousands of the finest cedar trees.* These furnaces supplied the local farmers with cooking vessels, agricultural implements and bar iron.

In the meantime, Kentucky and Tennessee were closer to civilization than were Georgia and Alabama, and in 1791 Bourbon or Slate Furnace was built near Owingsville, Ky., which had a production of about 3 tons per day.† Castings and bar iron were hauled seven miles to Licking River and floated to Cincinnati and Louisville. It is recorded that the workmen digging ore had to be guarded by armed sentinels against Indians, and it was necessary to build a strong block house on the principal ore bank. In 1810 this furnace contracted with United States Government to furnish cannon balls to the navy, and such material was actually used by General Jackson at the battle of New Orleans. In

*Armes, p. 30. †Swank, p. 283.

Tennessee a furnace and forge were erected in Sullivan County, near the Virginia line, about 1797. Some interesting illustrations of these old furnaces are to be found in "The Story of Coal and Iron in Alabama." Anyone traveling through the woods and finding one of these historical relics, unless he saw the slag beneath the weeds and brush heaps, might easily conclude he had run upon an abandoned lime kiln.

Development Before the Civil War.

In the nature of things, with the growth of population and the development of roads, and more particularly with the construction of railroads, the iron trade began to lose its local character and assume its normal aspect as a national industry. In doing this it met with some legislative discouragements, so that we cannot altogether console ourselves by referring to "the good old days," for we find a plaintive petition presented to the General Assembly of Pennsylvania * on November 30, 1785, asking for an additional duty to be laid upon foreign bar iron was adversely reported by the committee, and not until the adoption of the Morrill tariff, 1861, did this industry obtain a really solid foundation. It is true that the number of establishments multiplied greatly, for prior to the civil war we find a record in the South of no less than 198 furnaces, 217 forges and bloomaries, and 30 rolling mills, the vast majority of which were then passing or about to pass into a condition of "innocuous desuetude."

Some of these plants, however, had been notable ones. Steamboat men can be found to-day on the Mississippi River and Ohio, who will speak with pride of the boilers made from Hillman's charcoal iron plates produced on the Cumberland River with brown ore, charcoal fuel, and the puddled blooms pounded out by a big trip hammer. Memory suggests that the two negroes handling them under the hammer weighed over 250 pounds each. The success of the Hillman family in this Kentucky enterprise was a

*Swank, p. 495.

material factor in Birmingham developments later on. The charcoal furnaces from Rome, Ga., to Selma established a reputation for car-wheel iron, the low silicon cold blast charcoal pig being soft at the hub, easily turned, but taking a deep chill. Among those producers one notices the rise of the Noble family at Anniston into affluence, laying the foundation for the future success and development of that city.

Period of the Civil War.

As a traveler passes by railway train through a tunnel from one landscape to another in a different valley, so we pass through the period of the civil war. Enterprise throughout the South was necessarily almost stopped. Here and there a plant was maintained for the purpose of furnishing war-like supplies—cannon, shot, and swords; but more important still perhaps for military purposes were locomotives, wheels, rails, nails and bar iron. Establishments within range of Federal gunboats upon the rivers in some cases were injured or destroyed; in others, abandoned for the time. The organizations of peace were broken up, some plants taken by the Federal Government and operated for its own benefit, including the coal mines which later became the foundation of the Tennessee Coal, Iron & Railroad Co. Suffice it in a paragraph to say that this was, as all war times are, a period not of construction, but of destruction.

There are sixty pages in "The Story of Coal and Iron in Alabama," pages 134 to 194, giving a most interesting and detailed description of the developments and struggles of the iron makers of Alabama during the four years in question. It is interesting to read how during this period shot and shells up to 180 pounds weight were cast for the Confederate Government at Natchez, and later at Columbiana, Ala., plant being burned in Wilson's raid of 1865. Guns were manufactured 10 to 18 feet in length, and from 2 to 3 feet in diameter through the breech, cast and strengthened with wrought iron bands. Armor produced here for Confederate gunboats was in the shape of narrow thick

strips, usually 6 x 2 or 6 x 3, and as much as 10 feet in length. Admiral Farragut said after the fight in Mobile Bay concerning the Confederate steamer *Tennessee* that he poured the "whole broadside (of the *Hartford*) of nine-inch solid shot within ten feet, and not a shot entered the vessel." This certainly speaks well for the quality of the iron manufactured.

With the destruction of the older plants came the dawn of new things. Although Miss Armes (p. 194) says, speaking of the fall of Selma, "Beyond that burning city smoke the ruins of Oxmoor, Irondale, Tannehill, Brierfield, Shelby, and the rest, the coal and iron business of Alabama quieted now it seemed forever," but a resurrection day was coming very fast.

It is true that warm blast and higher pressure were being applied to charcoal furnaces, that the yield was steadily coming up and cost coming down, and the day was approaching when the enterprise of James C. Warner of Nashville, and Mr. L. S. Goodrich led to the construction of the largest charcoal furnaces yet known in the South, with kilns for the production of charcoal and the recovery of wood alcohol, but the days of the charcoal industry were fading fast and these efforts came too late.

The Coming of Bessemer Steel and Coke.

In 1864 the first Bessemer steel was blown in this country, and in 1867 3,000 tons of Bessemer ingots were produced; 1872, 120,000 tons; 1877, 560,000 tons, and in 1882, 1,696,000. As coming events cast their shadow before, it was increasingly evident that steel was about to displace charcoal iron, and the doom of many a small decadent Southern furnace, bloomary and rolling mill was already apparent. About this time a new factor was introduced, mineral fuel in the shape of coke, and a new era commenced.

Becoming convinced that the red powder on Montevallo road was iron ore, Mr. Grace, later sheriff of Jefferson County, owner of a farm at Grace's Gap, sent a wagon load of the ore * to a forge in Bibb County, where it was made

*Armes, p. 46.

into wrought iron. He made the first iron from Red Mountain ore in 1862 from what is now the Ishkooda property of the Tennessee Coal, Iron and Railroad Co. The purchasers were F. Gilmer and Jno. T. Milner, who with aid from the Confederate Government established Oxmoor furnace; and in later years purchased hundreds of acres for Mr. Thomas of Catasauqua. This formed the nucleus for the holdings of the Republic Iron and Steel Co. in Alabama.

In 1863 Mr. Daniel Hillman, who had made a handsome fortune from his Kentucky operations, visited the spot and invested in lands. These were afterwards opened by his son, T. T. Hillman, for account of the Alice Furnace Co. of Birmingham, in 1879, which began with an output of 53 tons per day; but this is anticipating. Towards 1870 plans were laid to rebuild the furnace at Oxmoor, accomplished in 1872, and at this point the financial assistance was obtained of Daniel Pratt, the cotton gin magnate, and his son-in-law, H. F. DeBardeleben, who was to become so active a figure in Southern development. The furnace went into blast in the winter of 1873.

At that time the South & North Railroad, now the Louisville & Nashville Railroad Co., had not succeeded in completing the railway, a 66 mile gap remaining unfinished between Decatur and Birmingham. There seemed great doubt as to whether money could be raised to complete this, and whether the road finally completed with the assistance of $2,200,000 from the State of Alabama would become only a feeder to the Alabama & Chattanooga Railway; but after much negotiation the enterprise was completed and opened just as the panic of 1873 broke upon the country. The Oxmoor furnace could not get out more than 10 tons per day. The price of iron fell from $40.00 to $8.00.* The plant was shut down and cholera swept over the district. Again it might seem as though the iron industry in the South was doomed.

In the autumn of 1873 the Eureka Company was formed, which employed Mr. L. S. Goodrich as superintendent. He reduced the fuel consumption from 196 bushels of charcoal

*Armes, p. 253.

to 123, and increased the output of the furnace from 8 tons per day to 18; and in the following year he proposed the use of coke instead of charcoal. After the lapse of some time, during which the officers of the company, swamped with debt, offered to turn over their furnaces to anyone who could handle them successfully, a meeting of citizens of the infant city of Birmingham raised an experimental fund, and five coke ovens were built.

Miss Armes graphically says (p. 260), "Affairs on the North and South Railroad were in sorry shape. There was neither coal, iron nor lumber for the road to carry; neither were there passengers, for nobody ever went anywhere in Alabama in those days. Between Decatur and Calera there was not enough traffic to warrant the operation of a passenger coach once a week, nor to operate more than one freight car a day. There was no revenue from any source. The experiment of making iron with coke seemed to every man in the district the last straw. Every eye was turned to Oxmoor. If it were unsuccessful, then the South & North Railroad must be forever abandoned in Alabama."

On February 28, 1876, the first coke pig iron was made in Alabama. As a result Louisville and Cincinnati interests, including the well-known names of Guthrie, Sloss and Sinton, became associated with the property. In 1876 and 1877 the furnaces were rebuilt fifty feet in height, making 20 to 25 tons each. And now set in a general era of development of coke using, hot blast furnaces. New York capital constructed Rising Fawn furnace in Dade County, Georgia, the first blast furnace in America to which Whitwell hot blast stoves were attached, the first departure from the old system of cast iron pipe stoves. My friend Thomas Whitwell—at whose Thornaby furnace, about 1860, I saw gas taken off by a down-comer rising out of the center, while top fillers dumped barrows into the open hopper around it—was deeply impressed with the possibilities of the American iron trade, and in addition to establishing an agency for his stoves, he assumed the leadership in an enterprise known as the Southern States Coal, Iron & Land Co. With English capital the company built

two furnaces in South Pittsburgh Tenn., for the purpose of combining with navigable water the coke and coals of Cumberland Mountain, and local red ores, and brown ores of East Tennessee. The first of these furnaces was blown in in May, 1879, having been constructed on English designs and erected and operated by English experts sent out for the purpose. It commenced with 45 tons per day output and crept up to about 70 tons under the management of my energetic colleague, E. C. Pechin. The furnaces were 70 feet high, 18 feet bosh, and 3½ pounds pressure of blast heated to 1300 degrees.

This was by no means, however, the first development in coke-made pig iron in the state of Tennessee, for a short blast had been made experimentally in 1859 in a furnace afterwards used by the Union troops as a lime kiln. The first furnace actually built on a commercial scale for coke fuel in Tennessee, or in the South at large, was that at Rockwood, Tennessee, in 1867, of which Captain H. S. Chamberlain, of Chattanooga, was the leading spirit. This plant has always been successful and active, and is so to-day.

The successful manufacture of pig iron with coke at Oxmoor naturally led to developments on a constantly broadening scale. The next few years witnessed the construction of the Sloss furnace in Birmingham; and the Birmingham Rolling Mill Co., a Louisville enterprise, taking root in 1879 for the manufacture of bars, sheets and plates. These were followed by the location of the Woodward Iron Co. furnaces, established by Wheeling, W. Va., capital in 1881, which commenced operation in 1883.

Predictions and Results a Generation Ago.

About this time the well-known statistician, Robert P. Porter, director of the eleventh census, and interested in the New York *Press*, visited the district and gathered together several interesting remarks and prophecies. Mr. Porter quotes among others the late Abram S. Hewitt, who said, "This region of Alabama . . . . is the only place on the American Continent where it is possible to make iron in competition with the cheap iron of England. The

cheapest place until now on the globe is the Cleveland Region, Yorkshire, England. The distance from the coal to the ore averages over twenty miles, while in Alabama the coal and the ore are in many places within half a mile of each other. I think this will become the region of coke-made iron on a grander scale than has ever been witnessed." Mr. (afterwards Sir) Isaac Lowthian Bell, a world-wide authority, said, "I will not say that Birmingham will furnish the world with iron, but I will say that she will eventually dictate to the world what the price of iron shall be." Mr. Porter, however, after quoting these two, and having selected Oxmoor as the cheapest possible point of production, says Willard Warner, former United States Senator, and experienced iron manufacturer, "admitted . . . . that there had been more capital sunk in Alabama than there had been dividends paid in the iron industry since the war." Samuel Noble, of Anniston, said, "You can go into the history of iron making in Alabama for the past twelve years and find it strewn with the wrecks of shattered hopes. In Georgia, if there is a single furnace in the state that for the past twelve years has not sunk the original owners all the money they put in, and not changed hands, I do not know it. Those of Tennessee have not fared much better. . . . The great trouble is we have not a home market. The whole state of Alabama cannot take the product of a single blast furnace for a month. The men who have gone into the iron business with a hope of making iron cheaper than England, and making nothing else, have lost their money."

About this time a remarkable real estate speculation developed throughout the South, which for some unknown reason was largely predicated upon the iron trade, and more particularly on the blast furnace department. Extraordinary scenes occurred of auction sales of lots, in forests of scrub pine, or even in bottom farm lands subject to overflow. Trains of Pullman cars were side-tracked bearing hundreds of eager bidders, largely prosperous Eastern business men who were willing to bid hundreds of dollars per front foot on the promise of a blast furnace at that point,

although the lands had previously been worth a very few dollars per acre. Numerous furnaces were built in pursuance of this remarkable craze. In two instances, at Fort Payne, Ala., and Middlesborough, Ky., open hearth steel plants were built at the same time.*

Necessity Enforced Improved Methods.

The multiplication of blast furnaces caused the inevitable result of bringing down the selling price of southern pig iron so low as to be largely unprofitable, and it began to be the study of each producer how he could reduce costs. This led to the building of larger furnaces and more careful preparation of the stock, and harder blowing, and 200 tons per furnace per day became the ideal to be attained.

This was accompanied by efforts to improve the quality of the fuel and reduce the consumption of coke and limestone. Various types of coal washers were introduced, including the Stutz, the Robinson-Ramsay, the Stewart, and others. The South took early part in experiments in the interest of economy and improvement, utilization of waste heat from coke ovens being effected by myself in 1879 at Victoria, Tenn., in raising steam for the fire brick works at that point, and by carrying the exhaust steam under the drying floor of the brick works. Some effort was also made to reduce the cost of brick for coke oven lining and the backing of blast furnaces by manufacturing them from local material in the Chattanooga District. A fair coke oven brick was made, but the clay bricks were not satisfactory owing to the large amount of combined water in the kaolin clay and the consequent shrinkage. The application of waste coke oven heat went ahead still more extensively under Mr. Erskine Ramsay at the Pratt Mines near Birmingham, and Mr. Charles E. Bowron at Tracy City, Tenn., where all coal mine haulage from drift mines, operations at the tipple, distribution of coal to the ovens, and pumping of water was accomplished by this agency.

In developing these plans of cheaper and larger output

*A. I. M. E. Vol. XXV. p. 527.

the district began to gain outside skilled operators, evidenced when in addition to the companies already named the Thomas family of Catasauqua, Pa., developed the Pioneer Mining & Manufacturing Co., near Birmingham, and gradually the Birmingham District became a hive of industry. Under the stress of competition, however, other furnaces and mills standing alone with old plants and equipment became obsolete and dropped either into the hands of their creditors or into idleness, and then disappeared from active competition. It is needless to compile a list of these tragedies in which many hopes were buried. It is kinder to draw a veil of oblivion and obscurity over them.

The Beginnings of Concentration.

The business of the South, as some of these old rolling mills went out of existence, concentrated more and more upon the production of foundry and forge pig iron in the Birmingham and Chattanooga districts, in which competition Birmingham had the advantage owing to the greater area and mass of its red ore supply and the greater, and indeed unrivaled, propinquity of its ore, flux and fuel. For a time it was assumed that Southern pig iron was worth at least a dollar per ton less than Northern iron, because of its content of phosphorus. In 1879 the writer was assured by the leading stove manufacturer of St. Louis that he could not dream of putting such an inferior material into his cupola, but would only use Hanging Rock and Glengarnock.

A factor arose, however, very helpful to the South, namely, realization by the trade about 1889 * of the effect of silicon in softening castings. It was found that using from 30 to 32 cwt. of coke with 12% ash it was easy to make high silicon pig. The writer has seen what the English call "glazed" pig iron put back into the furnace to be remelted, as unmerchantable, but it was not very long before the Southern high silicon, or "bright" iron, as we called it, worked its way into favor as a softener and scrap

*W. J. Keep—A. I. M. E. Vol. XVII. pp. 683 et seq.

carrier, and the virtue of pig iron, high alike in phosphorus and silicon, gave it preference for the production of stoves, radiators and architectural castings.

Under the pressure of competition by the larger companies questions naturally arose of decreasing competition by combinations, thus increasing resources and decreasing the expense of supervision and of distribution. In 1879 negotiations for the purchase of the Tennessee Coal, Iron & Railroad Co. by the Southern States Coal, Iron & Land Co. were arrested by the lamented death in his rolling mill of Thomas Whitwell. He was chairman of the English Company. This being followed up by the death of two leading stockholders, led to the reversal of the negotiations, and in 1882 the Tennessee Co. absorbed the Southern States Co. In 1886 the company extended its operations in Alabama and acquired the Pratt Coal & Iron Co., which had itself previously absorbed the Pratt Coal & Coke Co., the Alice Furnace Co., and the Linn Iron Works. In 1887 the company enlarged its operations by building the blast furnaces at Ensley, the most ambitious construction in the South up to that time and embracing four furnaces 80′ x 20′, equipped with 12 Weimer blowing engines 84″, 36″, 54″, and 16 Whitwell stoves 65′ x 20′. In 1892 this company enlarged further by the purchase of the DeBardeleben Coal & Iron Co., itself a combination embracing the Bessemer Iron & Steel Co. and the Little Belle Iron Co. Later in the same year it absorbed the Cahaba Coal Mining Co., which had itself previously acquired the Excelsior Mining Co. at Blocton, Ala. In 1899 the company bought a blast furnace plant at Sheffield, Ala., embracing 3 stacks, which purchase was subsequently relinquished.

In 1899 the Republic Iron & Steel Co., which had assumed a commanding position in the North by the purchase and consolidation under one ownership of many rolling mills, extended its operations to the South by purchase of the mineral lands and blast furnaces of the Pioneer Mining & Manufacturing Co., the Birmingham Rolling Mill, and the Alabama Rolling Mill. The president of the last named, Mr. W. H. Hassinger, became district manager

of the entire properties, and was ably backed by Mr. F. B. Keiser, with his Pennsylvania experience.

In 1887 new interests bringing New York and Richmond capital came into the Sloss Furnace Co., enlarged its capital and ownership of mineral lands, and built two additional furnaces in North Birmingham, presided over from 1888 to 1896 by Mr. Thomas Seddon. In 1899 the operations of this company were enlarged by the acquisition of the large area of brown ore lands previously owned by the Lady Ensley Iron Co., located in the Russellville District, and the three blast furnaces at Sheffield and Florence, to which these brown ores were tributary, the name of the company being then changed to Sloss-Sheffield Steel & Iron Co.

Development of Foundry Iron.

As a result of these various consolidations, competition for the foundry trade became intensified, and the prevailing low prices and excellent foundry qualities of Southern pig iron led to a large development in the South of the cast iron pipe trade. The foundries at Chattanooga, Bridgeport, South Pittsburgh, Anniston and Bessemer were then established, followed in subsequent years by those at Sheffield and North Birmingham. Until this trade became over-built, and riveted steel pipe became an opposing factor where heavy freight rates were involved, it was a profitable industry; the pig iron being the principal factor in the cost of the pipe, and this being sold at extremely low prices, with mere switching rates from the furnaces to the pipe foundries.

In 1888, prior to the establishment of these foundries, the writer analyzed the shipments of the largest producer and found that the product was shipped over thirty different states, and that the entire consumption in the South amounted to only 13½ per cent. The influence of the pipe foundry movement is rendered apparent by a similar abstract made in 1894–5, showing that while the product was then distributed over thirty-nine different states and five foreign countries, the Southern consumption had risen

to nearly 22 per cent, Alabama alone being advanced from seventh in order to second.

This movement was of supreme importance, for the Southern consumption of forge iron had been steadily dying out. The earnest efforts of General Powell and Mr. Schofield at Chattanooga, with Major Peters of Brierfield, had proved in vain. The relentless march of steel was pushing manufactured iron into the background, both as to plates and bars, and wire nails were making inroads upon cut nails. The works at Helena had also fallen by the way, although the Knoxville mill succeeded, and continues to this day.

Effects of Depression Beginning in 1893.

At this time the Southern situation became greatly aggravated by the national political changes resulting in the transfer of power to the democratic party, March, 1893, followed by the Wilson-Gorman tariff bill of 1894, which forced reductions of prices upon the industry, owing to the lower duties. To meet these lower prices, reductions of wages were sought, and the Birmingham District was confronted with a four-months' paralyzing strike of coal miners fighting against the reduction from 45 cents to 35 cents as the base price for digging the Pratt seam coal. After serious disturbances, involving the use of the militia, this was compromised on a 37½ cent basis. At the same time the country at large was most seriously affected by the Debs railroad strike, requiring the use of Federal troops from Chicago to restore order, and the disturbance reached down even to Alabama. There seemed little to encourage iron manufacturers in those days to continue in business. The strikes were no sooner over than another era of depression followed the threat of war with England over the Venezuelan question, and this in turn was succeeded by a recrudescence of the free silver question during the presidential campaign of 1896. Hardly was this settled by the election of McKinley and the adoption of a changed tariff policy than the situation was again clouded by the Cuban situation, projecting the shadow of the coming Spanish-American war,

and it was not until the close of that war in 1898 that the position clarified.

During this period of financial stringency, increasing the output of pig iron and decreasing the consumption as mills were pushed out of activity, there is little doubt that some producers would have stopped if they could have paid their bills. Heavy tonnages of iron were carried in warrant yards on borrowed money. Pig iron brokers made more money than the producers, either out of their sales commissions or by interest on the money which they advanced to the shippers against their bills of lading, sometimes every week and sometimes every day. Abnormal prices were made, which only covered in some places the cash out of pocket cost. The writer can remember one sale of 5,000 tons of No. 2 foundry at $6.25 spot cash, immediate delivery in one block, to meet a pay roll; another commercial transaction, a cargo of No. 4 foundry for Japan at $5.75, the balance of the sailing ship being filled up with coke. Needless to say such prices provided nothing for the depreciation of the plants which were standing still, or for the replacement of minerals which were being taken from the richest and most accessible points. Only the intrinsic value of the great mineral deposits of the South, and the faith of the various officials carried the district through those trying years.

Beginnings of Export Business.

Under these conditions, the familiarity of some engaged in the business with European conditions led to initiation of a foreign trade, shipping pig iron at ballasting rates of freight, in conjunction with cotton, largely to Hamburg, Bremen and Rotterdam for transshipment by barges to internal points in Germany and even Switzerland, and to Genoa, Venice and Trieste for Northern Italy and part of Austria. Shipments of smaller character went to almost every country importing cotton, the dead weight of the iron harmonizing with the lightness and bulk of the cotton. This trade became most important in bridging over the critical period, the shipments exceeding 100,000 tons per an-

num. But this was not enough relief. Claims for short weight after transfer to lighters were inevitable. Cars were occasionally left by impatient shipmasters, disputes and delays in settlement ensued, and the business at best was only one of marking time.

Beginnings of Steel Making.

It was inevitable under these conditions that the minds of producers of pig iron should turn with anxiety to the question of the production of steel. During the late seventies and early eighties experiments had been carried on in Chattanooga by Mr. Leighton, making small amounts of open-hearth steel in an experimental way. These were little more than enlarged laboratory experiments, and ceased with his working capital. The Roane Iron Co., always successful as the owner of the Rockwood furnaces, undertook the manufacture of Bessemer rails at Chattanooga, making the iron from a mixture of Cranberry ore and another found near Morristown, East Tenn. The latter was irregular in phosphorus, and the deposit limited. As the rails produced were too high in phosphorus, the experiment was discontinued and the mill was ultimately sold and broken up. The experiment was deeply interesting, and conducted with vigor and intelligence.

Before the plant was broken up, however, it afforded opportunity for an adequate demonstration in the way of Southern steel making under the auspices of the Southern Iron Co. In 1890, under the control of N. Baxter, Jr., and A. M. Shook, of Nashville, for so many years the leading officials of the Tennessee Coal, Iron & Railroad Co., the Southern Iron Co. undertook the experiment on a commercial scale of the manufacture of open-hearth steel in the South from Southern pig iron. In a small way this had been done in Birmingham in 1888 by the Henderson Steel Co. with the large use of fluorspar as flux. About 1800 tons of steel had been made there, operating in a small way and necessarily at a high cost. For the experiment at Chattanooga by the Southern Iron Co. about 800 tons of South Pittsburgh iron was manufactured under

1 per cent. silicon and .6 per cent. sulphur, the phosphorus approximating 1.40 per cent.

The steel thus made was available for trial on the occasion of the joint visit of the American Institute of Mining Engineers, the British Iron and Steel Institute, and Verein Deutscher Eisenhuttenleute in 1890, at which time, in the presence of Mr. Kirchoff, editor of *The Iron Age*, a variety of tests of the physical qualities of the steel were made in a most severe and searching manner. It had always been contended that our Southern iron contained too much phosphorus for either the Bessemer or the acid open-hearth process, and not enough for basic Bessemer, and that it contained too much silicon to be used successfully in the basic open-hearth furnaces. Mr. Barton is quoted as saying * that experiments were made with the concurrence of Mr. Talbot and reduced the silicon in the Ensley pig iron by pouring it through a bath of blast furnace slag, but that whilst this reduced the silicon, it absorbed a fatal amount of sulphur from the slag. The writer was deeply interested in Mr. Talbot's process, which was invented and developed at Chattanooga, and became an insistent advocate of a move towards the production of steel by the Tennessee Coal, Iron and Railroad Co., in whose service he was then employed.

In April, 1881, Mr. S. G. Thomas, one of the joint inventors of the basic process, had been the guest of the writer at his home in South Pittsburgh, Tenn., and a negotiation was then started for the English Company acquiring the sole right to manufacture steel under that process in the South. This negotiation lapsed owing to the lamented death at an early age of the distinguished inventor. At a later date the Tennessee Coal, Iron and Railroad Co. became the owner of Jacob Reese's patent for the duplex process, but the information obtained seemed to indicate so great a loss by oxidation and slagging in the double process as to make it undesirable.

No one in the South had the necessary money to go into such a plant. It was necessary to enlist Eastern

*Armes, p. 434.

capital. At a dinner in Birmingham Mr. Andrew Carnegie had said to President Baxter that the Tennessee Coal, Iron and Railroad Co. owed it to the district to make steel here, but the Tennessee Company had all it could do in those trying days to keep hot the irons which were in the fire without burning any of them. Matters, therefore, rocked along until after the development of large beds of dolomitic limestone in East Birmingham. Mr. G. B. McCormack said to his colleagues in the Tennessee Coal, Iron and Railroad Co. that he felt sure a liquid slag could be carried on a burden heavy enough to hold the silicon below 1 per cent. After making a few tests at the Alice Furnace, casting in sand, commencing July 22, 1895, the furnace was equipped with chills, and regular commercial practice commenced August 15th. In a very short time the entire make of the furnace was being sold to the Carnegie Steel Co., Illinois Steel Co., and other well known companies in the North, under a guarantee that the silicon and phosphorus should run below 1 per cent.

This continued for over two years, by which time the most skeptical were satisfied that suitable iron could be made locally for conversion into steel. The next question arose as to the size and scale of the plant necessary to handle such iron commercially. In 1896 a subscription had been raised among the citizens, Birmingham contributing approximately $75,000, towards the construction of an open-hearth furnace at the Birmingham Rolling Mill. On July 24, 1897, the first casting was made at that plant, bottom-poured ingots weighing about 1,400 pounds each. The experiment was too small to be a commercial success, and the company failed in 1899.

Large Scale Steel Production Begun.

In December, 1897, President M. H. Smith, of the Louisville & Nashville Railroad Co., came to Birmingham and told the officers of the Tennessee Coal, Iron and Railroad Co. that his company had invested many millions in and around Birmingham, that the iron manufacturing

plants were wearing themselves out, exhausting their most accessible materials, and making no money, and that unless steel was manufactured on a large scale, the district would be a failure. He said that the Louisville & Nashville had too much invested to sit still and watch that failure; that the Tennessee Coal, Iron and Railroad Co. owed it to itself and to the district to go into the manufacture, and that if it refused to do so, the Louisville & Nashville would contribute towards the enlargement of the plant at the Birmingham Rolling Mill. An earnest effort was then made by President Baxter and Vice-President Shook to obtain the concurrence of the directors in New York in such a departure, but the menace of the then impending Spanish-American war was such that they refused to consider it. They passed a resolution authorizing the officers to subscribe $100,000 towards the enlargement of the Birmingham Rolling Mill plant, payable in coal and iron over a year, and to contract to stay out of the steel business for a period of years.

The writer of this article challenged the wisdom of this action by letter, which, with the answer thereto, appears in Miss Armes, pp. 463–4. As a result of this earnest remonstrance the necessary authority was obtained, and after six months' active co-operative effort on the part of the various officials of the Tennessee Coal, Iron and Railroad Co., $950,000 was raised in New York and $150,000 in Birmingham, and an open-hearth plant was located at Ensley upon the plans of The Wellman-Seaver Engineering Co., of Cleveland, who had been designated by President Smith, of the Louisville & Nashville Railroad Co., for that purpose. This plant was built under the name and charter of The Alabama Steel & Shipbuilding Co., common stock being owned exclusively by the Tennessee Coal, Iron and Railroad Co. Ten tilting open-hearth furnaces, theoretically averaging 50 tons per heat and two heats per day, with a 42-inch blooming mill.

The average production in the first year of operation did not exceed 300 tons per day. The pig and scrap process was employed, but the possible production of the furnaces

was held down by the unsatisfactory working of the ingot-heating arrangements, the designers having equipped the plant with a tunnel through which the ingots passed on their stools, instead of the customary soaking pits. It was found in practice that the heating was irregular, some of the ingots coming out too cold for rolling, whilst others melted down on the stools. The company was not equipped to manufacture anything but billets 4″ x 4″ square and upwards, and it was soon apparent that the problem of finding a market had changed its character, but was still in existence.

Some billets were sold in England, but the principal delivery was to the Alabama Steel & Wire Co., which built a plant abutting upon the Ensley steel works. This was constructed by Chicago and Joliet capital, under the management of E. T. and G. H. Schuler, of Chicago, and C. E. Robinson, of Joliet. Accustomed to Bessemer steel, the results obtained from the open-hearth product were not satisfactory, and in 1903 the company built a plant at Gadsden to supply its own steel, the plant embracing a blast furnace, four 50-ton stationary open-hearth furnaces, and a 36″ blooming mill. This removed from the Tennessee Coal, Iron and Railroad Co. the largest consumer of its billets, and forced the completion of finishing mills into which the product might be turned.

In 1906 John A. Topping became chairman of the Tennessee Coal, Iron and Railroad Co., being also president of the Republic Iron and Steel Co., and during the ensuing two years considerable enlargement of the steel works was undertaken with the assistance of Mr. F. H. Crockard, who became vice-president and general manager of the Tennessee Coal, Iron and Railroad Co. and district manager of the Republic Iron and Steel Co. The enlargement of the plant and the reconstruction on a stronger and heavier scale was undertaken upon the basis of using the duplex process instead of purchasing scrap in the open market. The amount of money required for reconstruction of the steel works and subsidiary plants was very great, and precluded the possibility of the payment of dividends upon

the stock. This stock was, therefore, held by a syndicate.*

Recent History.

Miss Armes states that the sixteen men whose names are given held more than one-half the entire capital stock, and that about $7,000,000 being expended during the two years, a large amount of this was borrowed through the firm of Moore & Schley, which borrowings in the autumn of 1907 amounted to millions of dollars. A large amount of this was with the Trust Company of America, which also held and controlled among its pledged assets the control of Central Railroad of Georgia. At the height of the panic of October, 1907, when Moore & Schley were called upon to take up the Tennessee Coal, Iron and Railroad Co. stock, it could not be done, and the credit of that great firm, as also of the Trust Company of America, was apparently endangered. On November 5, 1907, as a result of suggestions made at a conference held by leading financiers at the house of J. P. Morgan, two transactions were carried into effect, the sale of the controlling interest in the Tennessee Coal, Iron and Railroad Co. to the United States Steel Corporation, and the sale of the controlling interest in the Central Railroad of Georgia to E. H. Harriman and associates, controlling the Illinois Central Railroad, and making the two an air line from Chicago to the South Atlantic. The simultaneous accomplishment of these two transactions released unavailable assets, and gave both quick assets, money and credit to the concerns that were threatened. The runs stopped, public excitement subsided, and the great panic of 1907 was at an end.

The United States Steel Corporation had thus for the first time become interested in the South, and it is only necessary to refer to the minutes of the Birmingham Chamber of Commerce to see the cordial approbation of the South. The advent of the Steel Corporation was hailed with delight by all who were unprejudiced; and, speaking as one who has never owned a single share of its stock, the

*Armes, p. 515 et seq.

writer feels that it has been continuously the greatest single source of benefit that has ever come to the manufacturing South, whether considered from the standpoint of the magnitude of its importance or the breadth and liberality of its policy. (Applause.)

During this time, however, in the neighboring state of Georgia they had not been standing still. In 1900 the Atlanta Steel Co., under Geo. W. Connors, was organized to make hoops and cotton ties, and started with one 8″ mill, buying billets. In 1902 a light rolling mill was added for re-rolling. In 1905 two 35-ton open-hearth furnaces were added, a blooming mill, rod and wire mills to take over the surplus steel. In 1906 the company entered the production of spikes, and in 1908 that of woven fence. It produced also wire nails and barbed wire. This plant possessed no raw material of its own, buying both pig iron, scrap and coal. Under aggressive and enlightened management it has kept pace with scientific development, utilizing its exhaust steam by low-pressure turbine, and under the presidency of Mr. T. K. Glenn maintains good standing in the competitive field.

In 1908 Mr. Geo. W. Connors withdrew from the Atlanta Steel Co. and took the old tube mill at Helena, Ala., changing it into a hoop and cotton tie mill, having one 9″ train with a capacity of 15,000 tons annually, under the title of The Connors-Weyman Steel Co. They purchase their billets, but they mine their own coal.

The panic of 1907 brought down the enterprise at Gadsden of the Southern Steel Co., which had encumbered itself with the purchase of various properties, widely scattered, handicapped by inter-plant freights, and with brown ore deposits pockety in character, seriously affected by the intrusion of sulphur, and largely worked out, whilst the red ore deposits were squeezing down in thickness, becoming interfoliated with slate. After two years the enterprise was reorganized with the assistance of English and Dutch capital, and under new management, which provided additional money, removed the rod and nail mill machinery from Ensley to Gadsden, and built an extremely fine and

well-designed wire drawing and finishing plant in connection therewith, and a combination Morgan roughing train and Garrett looping rod mill of 500 tons daily capacity. Unfortunately, no part of the money subscribed was expended in acquiring more reliable bodies of raw material, and the capitalization was entirely beyond the productive capacity of the plant, handicapped as described. In 1912 they passed into the hands of the writer as receiver and trustee, and a new company was formed among the creditors and stockholders of the old one for the purchase of such of the assets as was deemed expedient. This company, under the name of the Gulf States Steel Co., is operating at a profit, free from bonded debt, and has an ingot capacity of 600 tons per day, making 18″ x 20″ ingots of 6,000 pounds weight. It produces plain and galvanized wire, barbed and woven wire fence, nails, merchant bars, and is arranging for the production of tie plates. It has also corrected the deficiency of its predecessor by the purchase of 1,604 acres of Red Mountain ore, near Oxmoor, proved by the drill 19 feet 3 inches thick, over 38 per cent. metallic iron, and self-fluxing. This is being developed by a slope 9′ 6″ x 17′ at a pitch of 50½° which will intersect the ore at a lineal depth of 2,482 feet, and at the time of this writing is about 1,260 feet deep. No water has been encountered in driving this slope below 384 feet level, where the direct cementation process was applied and the water stopped with a minimum of trouble and expense. The plans contemplate an output of 2,000 tons per day from this operation.

The United States Steel Corporation's Operations.

Since the advent of the United States Steel Corporation into the district, the development of the Tennessee Coal, Iron and Railroad Co. has been continuous under the management of President Crawford, Vice-President Crockard, and Mr. H. C. Ryding, assistant vice-president. The writer was asked to write a historical sketch. Mr. Crawford and his associates loom up before our eyes at this meeting, large physically, mentally, and from a standpoint of genial good fellowship. Their works will be open to the

inspection of the members of the Institute, and will speak for themselves infinitely better than the writer can speak for them. It is only, therefore, for members of the Institute who cannot be present, and incidentally to bring a historical sketch, fragmentary though it is, down to date that the following outline description is given.

The Tennessee Company's Ensley plant of to-day embraces 6 modern furnaces, 90′ high, from 21′ to 23′ bosh, two of which have the 12″ lining with external vertical water cooling, the average production of basic iron varying from 350 to 400 tons from Red Mountain ore. Four furnaces, of which two are rebuilt at Alice and Oxmoor, vary between basic and foundry. Four furnaces at Bessemer are restricted to foundry iron, and one is held for ferro manganese, or special purposes. The company's operations at Ensley embrace under the duplex process eight 100-ton tilting open-hearth furnaces supplied by two mixers, 250 and 600-ton capacity, and two 20-ton Bessemer converters with total ingot capacity of 75,000 tons per month. Ingots 24″ x 24″ are reduced at the blooming mill to 8″ x 8″, or slabs up to 24″ wide. These are reduced to 4″ x 4″ billets for the company's merchant mill at Bessemer, or for the American Steel & Wire Co.'s plant at Fairfield, or for the open market, or are alternatively delivered to the rail mill. The finished product of the rail and finishing mill is about 45,000 tons of rails, and at Bessemer 6,000 tons of plates, angles and merchant bars.

The American Steel & Wire Co. has at Fairfield a new plant, embodying 24 acres under roof, containing a rod mill driven by electric motors, with wire department equipped for the production of plain and galvanized wire, nails, barbed and woven fence wire, etc. This plant runs entirely on steel furnished by the Tennessee Company, which also furnishes the motive power.

The Southern Ore Supply.

It is impossible to pass away from the iron and steel of the South without a reference to the ore supply. It was supposed for many years that as mining operations were

pushed down the pitch of the Red Mountain vein, the ore would (as it did near South Pittsburgh, Tenn.) run into the original gangue and become lean. This view was held even so late as 1910, when Bulletin No. 400 of the U. S. Geological Survey was published. Mr. Burchard's estimate * gives 796,896,800 long tons of red ore in the Birmingham District available for recovery and of commercial value. This is excluding seams too thin to be worked, and too low in metallic iron. A reference to the map on p. 128 of this Bulletin shows Oxmoor on the very verge of the available territory, and the drilling which has been done by the Woodward Iron Co., the Tennessee Coal, Iron and Railroad Co., and the Gulf States Steel Co. has developed much additional territory which Mr. Burchard's conservative estimate did not include, although on his own figures, he asserts reserve sufficient for 100 years on the present requirements of the district. The opinion of the writer is that, as the ore is both becoming thicker and slightly richer as it flattens out into the basin, Mr. Burchard's estimate of the resources of the district will need to be revised upwards.

The South Progressive.

It is impossible within the limits of a 30 minutes' paper to do justice to the subject of scientific development, but it is fair to say that the South has always been in keen sympathy with every method of improvement, although the scarcity of capital for many years restrained local management from such development.

During the past sixteen years there have been constructed at Ensley 240 Semet-Solvay by-product coke ovens, of which 120 were contracted for by the officials of the Tennessee Company in 1898, who had, despite the war clouds, sufficient confidence and interest in the process, this plant being the first in the South, and one of the earliest in the United States. Sixty of the same type at Holt, Ala., for the Central Coal & Iron Co., whilst within the past four years there have also been constructed 280 Koppers

*Bul. 400, p. 133.

by-product ovens at Fairfield and 170 by the Woodward Iron Co. at Woodward, Ala. The gas from these ovens is used at Ensley in the raising of steam and calcination of lime and dolomite, and most important of all, is now being used with much success in the direct operation of the open-hearth furnaces. At the foundry at Holt, where soil pipe is produced on a large scale, gas has been used for raising steam, melting iron, drying moulds, and at one time for nodulizing. Sulphate of ammonia and benzol are also produced at Ensley and at Holt, and a benzol plant is building at Woodward. The large development of the cast iron pipe industry in the district has afforded an improved market for the tar; this is still further needed in the improved method of road preparation under modern practice.

Exhaust steam collected at Ensley is utilized by four 3,000 K.W. low pressure turbo-generators furnishing power, not only for the entire plant of the American Steel & Wire Co., but also for the operation of the Tidewater Street Railroad. And at the Atlanta Steel Co.'s plant the exhaust steam is similarly utilized for running the low pressure turbine at the blooming mill, and at Woodward by-product oven gas is carried to the boilers supplying turbo-generators providing current for the company's ore and coal mines.

Various experiments have been made from time to time in the utilization of blast furnace slag, either for ballast, for mineral wool, or for cement. A more interesting development is the production to-day from open hearth slag of phosphatic fertilizer, 80 per cent. of which will pass through 100 meshes to the inch. The casting machine was a product of the South, to the credit of Mr. Uehling, whilst employed by the Sloss Company, and whose patent was purchased by the Carnegie Company. At a later date the Tennessee Company installed a casting machine on the Jones & Laughlin type.

Arrangements have been made for the introduction of hydro-electric power and the installations are now proceeding by which a large capacity generated by the Alabama Power Co., on the Coosa River, will be within a few weeks delivered to the steel works at Gadsden, mines on

Red Mountain, and to the mining operations of the Alabama Company at Attalla.

The Southern manufacturers of iron and steel realize that their advantages are very large deposits of self-fluxing ore and coking coal in close proximity; a fairly abundant supply of colored labor, docile and responsive to kindly treatment, but not of the highest efficiency; a balmy climate free from extremes, permitting outdoor work the year round, without danger from freezing weather; and with some prospect of navigation in the near future by barges to tidewater. Against these advantages must be set the distance from densely populated states involving a sacrifice of profits by the necessary freight rates to reach the markets of the world; these markets, however, are put nearer to the South by the opening of the Panama Canal. The possibilities incidental to the barging of heavy material from the Birmingham District to Mobile at lower cost than present railroad rates, with the possible upbuilding of Mobile Bay by ship yards, graving docks, coaling stations and works for the construction and repair of marine engines, inspire the manufacturers of the South, drawing lessons from the past, to go forward facing the future with patience and with courage. (Applause.)

JUDGE GARY: The paper has been so interesting that you will be surprised to know that the gentleman was on his feet for more than one hour.

In justice to myself I will say that I spoke of Mr. Bowron, not as an old man, but as an old friend.

We will now have a brief discussion of the paper by Captain Chamberlain, President of the Roane Iron Company, Chattanooga, Tennessee.

THE HISTORY OF THE IRON AND STEEL INDUSTRY IN THE SOUTH

Hiram S. Chamberlain

President, Roane Iron Company, Chattanooga, Tennessee

The history of the Iron and Steel Industry of the South has been so thoroughly covered in Mr. Bowron's paper that it seems to me there is little more to say, although there are some facts not mentioned by him which may have an historic interest in connection with the topic under discussion.

The Early Iron Industry.

About 1784 iron manufacturing was introduced into Southwest Virginia, North Carolina and Eastern Tennessee. Charcoal and brown and red ores of the same character as those of Eastern Pennsylvania, Virginia, Georgia and Alabama were used. I might mention that the red fossil ores of Eastern Tennessee were used as well as the brown hematites.

The low stone stack with cold blast and the primitive Catalan forge with water blast were the appliances adopted, and very little advance was made before the War of the Revolution. One thousand to three thousand pounds per day of pig iron and from five hundred to one thousand pounds per day of blooms from the forges were considered a satisfactory output although this was increased somewhat in later operations.

It is hardly necessary to say that from what I can learn the early experiences of Southern manufacturers were about as full as disappointments and ups and downs as in the North, or as later experiences in the South. It was a rule of thumb proposition—mostly thumb—and the progress from Tubal Cain was about nil. Both North and South the primitive Catalan forge and the diminutive charcoal furnace covered the entire field of iron smelting on this continent.

The cast iron mostly went into hollow-ware and the blooms into horse-shoes, wagon tires, nails and what was known in the South as "bull-tongue" plows and like necessities for an agricultural population.

During the war, while operating at Knoxville a small rolling mill, with one small puddle furnace and one small heating furnace, built by one Jones from Pennsylvania, I used a considerable amount of these blooms and puddled all the iron that could be obtained from the Virginia and Tennessee forges and furnaces. The product was very useful to General Burnside's army during its occupation of Eastern Tennessee from 1863 to the end of the war. I might mention that the analysis of a sample of iron made at the old George Gordon Furnace situated on the present property of the Roane Iron Company, and made from the same ores now worked by the Company, had a phosphorus content of 1.14 per cent., while the Rockwood iron has phosphorus about 1.40 per cent. At the beginning of the war there were many of these furnaces scattered along the mountain streams of Virginia, North Carolina, Tennessee and Kentucky producing practically all the iron used in the central South, outside of that required by the very limited railroad, mileage.

Concerning the methods of this early iron making, I beg to quote from a letter received in answer to an inquiry by me from Joel T. Pyott, a very old citizen of this State, as it seems to be a very clear record of his early experience.

Interesting Letter of Joel T. Pyott.

Sometime early in the last century George Gordon owned and operated an iron forge on White's Creek which stream is the dividing line of Roane and Rhea Counties. At a later date, about 1820, Mr. Cravens of Chattanooga erected a cold blast charcoal furnace in the same locality. This furnace was operated for twenty years. About the time this furnace went out of commission, a blast furnace of larger capacity was constructed on this same creek, and was at first run by water power alone, but it was later supplemented by steam power. I have been told this furnace had a capacity of turning out four tons of pig iron per day. At the present date this seems rather small but there were some compensating advantages in that this pig iron brought from $40 to $60 per ton.

This iron works, a furnace and a forge, was owned by a company. One of the owners was a Mr. Lincoln, a near relative of Abraham Lincoln. When I was a boy I carried the mail by this place, called Eagle Furnace. The post office was at the Lincoln residence. These works stopped about

the year 1859, but the forges of which there were four on this creek did not all cease work until 1875.

The metal was made direct from the ore and never reached the molten stage. Only the dross would melt and the iron would weld together and form in a mass at the bottom of the fire place which would be raked out with an iron hook. To this a bar of iron would be welded for a handle to hold it under the hammer to be drawn out into the desired shape. One forge hammer was sufficient for three fire places, which fire places were open in front and about twenty inches wide.

The strangest thing about these iron works to me was the blast which was made without fan or bellows by the fall of water alone. There was a flume that carried the water to the wheel that worked the hammer. This flume would necessarily be some distance from the ground. At the bottom of this flume a hole was made that conveyed about five inches square volume of water through a wooden box pipe to a box below about two feet square, and about thirty-two inches high. The water fell on a piece of timber at the bottom of the large box and dashed into spray. This produced the blast. At the upper end of the splash box a hollow trunk of a sour wood tree was connected to convey the blasts, then another section of the same kind of timber would be connected by the hide of the leg of a dead cow or beef, having been taken off whole, and these hides would be fitted over the ends of the timber and tacked thereto making an air tight joint. This process would be continued and the flexible joints would be turned about in any way to reach the furnace. When within about eighteen inches of the fire an iron pipe would be connected to convey the cold blast to the fire. Sour wood timber was generally used for blast piping from the fact that it was of small growth for timber and much of it hollow.

I was raised in the Tennessee Valley between Pine and White's Creeks, and within hearing of the hammers of these eight forges. It was then that I learned that sound could travel better during cold weather; for during a crisp, cold, frosty morning the sound of these forge hammers could be heard more distinctly than during any other kind of weather.

It took a large volume of water to run these forges. Consequently they were located only on the larger streams and could only run during winter stage of water, but the iron workers could be busy all the year chopping wood, charring it to coal and getting in a supply of ore and coal.

This man, Gordon, who erected his iron works within four miles of what was known then as the "Indian possession" was among the pioneer iron manufacturers in lower East Tennessee. He was an eccentric man and a person of wealth of his day. He owned land and negroes. At that time the punishment for slaves for all offenses, below capital crimes, was whipping. Gordon had a negro named "Pomp" who was arrested for stealing chickens and brought before a Justice of Peace for trial. Gordon, as was generally the case with the owners, went Pomp's bond for his appearance and attended the court to see that his negro had a fair trial. In the afternoon Pomp was seen going toward home. He was asked, "How did you come out, Pomp?" He said, "I stood my trial, took thirty-nine lashes, paid the cost and came clear." (Applause.)

Captain Bill Jones.

It seems that immediately before the war Mr. Cravens built a small furnace in Chattanooga which chilled in blowing in and never made any iron. Mr. Giles Edwards of

Pennsylvania was engaged to build the furnace and a factor in this early venture was our old friend, Bill Jones, afterward known as the most important man in the Carnegie scheme. He followed the Loyd family (Mr. Loyd was to be Edwards' founder) to Chattanooga, the attraction being Harriet Loyd, whom after great tribulations, he finally married before leaving the city. Captain Jones helped build the furnace; worked in Webster's machine shop and then ran a saloon and billiard room for a time. But early in 1861 matters got pretty hot for Northern men in Chattanooga and, receiving some warning letters and getting into a row with a crowd of young bloods who had a lively interest in his politics, with a billiard cue he cleaned out the whole lot in short order. He was arrested, but knowing the officer, was taken to the Nashville and Chattanooga Railway yards, put on an engine with the engineer and went to Nashville, was transferred to another engine and taken to Louisville and then worked his way on a boat to Cincinnati and Pittsburg, finally reaching Johnstown late in April, 1861.

My acquaintance with Captain Jones began in 1878 when the Roane Iron Company put down two 10 ton acid open hearth steel furnaces, and knowing of the blooming mill used by him at Braddock I contracted with Jones for drawings and had one built by McIntosh & Hemphill of the same pattern, only heavier, which was used while we were manufacturing steel in Chattanooga. It was a sad day when Jones was killed by a gas explosion in one of the Carnegie furnaces a few years later.

I could say much more of Captain Jones as the history of steel making in the United States cannot be written without giving him a most prominent place in the record. During the war he served as Corporal in the 105th Pennsylvania Volunteer Infantry and later as Captain of the Independent Company of Pennsylvania Volunteer Infantry.

The Roane Iron Company.

Covering the period since the war and especially that immediately succeeding the war, something of the history and experience of the Roane Iron Company may indicate

in a special manner more fully than in any other way what has taken place in this newly discovered field for iron and steel manufacture.

It must be remembered that conditions were different in the South to those in the North. There were practically no manufacturers or sympathy with manufacturing enterprises, no skilled labor, no capital, no experience of other people to go by, while there was an over supply of Kuklux and other like peaceful agencies. As for bank accommodations 1 per cent. per month was the minimum. Nor did the South seem an inviting field for Northern investments.

The Roane Iron Company was organized June 18, 1867, by W. O. Rockwood, John T. Wilder, Antrim R. Forsyth and David E. Rees of Indiana, John M. Loyd of Cincinnati, and H. S. Chamberlain, with a capital stock of $100,000. A contract was let for building a bank coke furnace with pipe stoves of fifteen tons per day capacity. The furnace was to be in all respects an up-to-date plant. This does not bear evidence of being a very big undertaking, but it was such in 1867, with no knowledge of the ore, coke or limestone. I do not think there was a chemist at any furnace plant in the United States at that time. With the South in the condition it was so soon after the war, there was a very doubtful and uncertain market.

As showing conditions at that time, I had opened in 1866 a small coal mine at Coal Creek near Knoxville, Tenn., and in looking for a market found that wood was used exclusively on the railroads, and outside of the seaboard towns gas for lighting and domestic purposes was made entirely from pine knots gathered in the adjacent woods and hauled in mule carts to the works. A President of one of the gas companies explained in objecting to coal that pine knots went through the metre "so like the devil".

The First Coke Pig Iron in the South.

The Roane Furnace was built and for the first year, 1869, the output was 4,270 tons of good merchantable iron at a cost of $25.49 per ton, and the next year at a cost of $14.47 per ton. This was the first coke iron made in the South but

there has been a good deal made at Rockwood since that time.

A narrow gage railroad with strap rails was built from the furnace to the Tennessee River, five miles away, and with mules, and afterward with a small engine, the iron was hauled to the Tennessee River and shipped to Chattanooga, Knoxville and other favorable points. It is needless to say that this furnace was replaced by another and better one when necessity dictated, until now the present plant of two modern furnaces is in every way,—design and equipment, equal to any in the South. The coal opening is within 200 yards of the furnace, producing coal for coke of an excellent quality and structure. Although high in ash (12½ per cent.), it is low in sulphur and well adapted to smelting purposes. The upright vein of our red fossil ore which is self fluxing is about four feet in thickness and extends some ten miles on the Company's property yielding on an average of 40 per cent. metallic iron, phosphorus about 6 per cent., lime 10 per cent. to 11 per cent., and sulphur .05 per cent. The Cincinnati Southern Railroad now runs near the furnace and directly through the entire property. In no place is the railroad so much as one half mile from the ore vein. With the exception of an occasional stop for repairs at least one furnace has been in blast continuously at Rockwood for the past forty-five years.

Re-rolling Iron Rails.

In 1864 General Sherman built a rolling mill for the Government at Chattanooga for re-rolling iron rails as the needs of the army might require. Wm. Fritz then in the 15th Pennsylvania Cavalry, a brother of John Fritz, was superintendent of construction and needless to say he put down a good plant. At the close of the war the mill was sold to Abram S. Hewitt of New York and associates, and in 1870 it was purchased by the Roane Iron Company and operated by it until 1877, when steel rails superseded iron and the mill was closed. The old iron rails from all the roads in the South were brought to the mill, cut up and made into piles with new puddle iron for heads and re-rolled into sections of from fifty

to sixty five pounds weight per yard and returned to the several roads.

The terms for re-rolling were usually a ton of old rails and according to business conditions $20 to $35 per ton cash. At the time Northern mills were doing the same thing and I had many a tussle for the Lousiville & Nashville R. R. business with Cambria, Carnegie, Chicago, Indianapolis, Columbus and Springfield mills.

First Steel Made in the South.

The Company then, 1877–1878, put down two 10-ton acid open hearth steel furnaces with the idea of holding the Southern trade. When the work was commenced steel rails were selling at from $80 to $90 per ton at Northern mills, but within a short time after the first rails were made the price had fallen to $35. So owing to excessive cost here in comparison with the Northern makers who used Lake Superior ore and Connellsville coke, the works, after a time, were closed again. Ore from Cranberry, N. C., was used, as also ore from Cartersville, Ga., and Maryville, Tenn., with scrap. But this mixture was unsatisfactory and great difficulty was experienced in keeping the phosphorus within the Bessemer limits. Some 50,000 tons were made and some of these rails are still in use on the standard gage road on Lookout Mountain and in the railroad yards about Chattanooga.

This was also the first steel made in the South and, while not a successful venture, showed that we were not behind our northern friends in the effort and had conditions been favorable might have been in the procession with them.

I might say that a five ton Bessemer Converter was also installed in 1886 by the Company and the first blow made May 7, 1887, being the first Bessemer steel made in the South. For this process the pig iron was made at the Rockwood and Citico furnaces from ore brought from the Cranberry mines in North Carolina; also we imported a considerable quantity of Bessemer pig iron from England.

While prices for rails remained at the topnotch we showed

a satisfactory profit, but this was not for long and the works were closed permanently. From experience gained too late it seems to have been an unwise undertaking to build either an open hearth or Bessemer plant, but steel rail manufacturing was then in its infancy, and we had a rolling mill and the market. Little was known of the Lake Superior ores and so we took our chance.

In 1889 the property at Chattanooga was sold to the Southern Iron Company. Messrs. Thomas and Gilcrist having brought out the basic steel process, A. M. Shook, manager, and associates employed Mr. Benjamin Talbot of Wales to put down two 10 ton basic open hearth furnaces which were operated a short time, making the first basic steel manufactured in the South, September 15, 1890. When the plant proved unsuccessful financially it was closed down permanently. Basic Steel manufacturing was unknown at the time and the product could not compete successfully with the Bessemer Steel made in the North. The Talbot furnaces of the present day were the outcome of the experience gained at the Chattanooga plant in 1890 and 1891.

Danks' Rotary Puddling Furnace.

The Roane Iron Company had a very interesting experience during the operation of the rolling mill in 1872 with the Danks puddling furnace. This furnace was patented by Samuel Danks of Cincinnati. It was a revolving cast iron barrel, lined with refractory material and pulverized plastic iron ore, driven by a single engine. The puddling was accomplished in the revolution of the barrel in which the iron was charged and the work done effectively and rapidly. As much as 1,000 pound balls of good puddle iron were produced at a charge. The Company installed ten of these furnaces as did Jones Brothers of England, and operated them until it became evident that the cost of puddling was much greater than in the old style furnace. Then the Danks furnaces were taken out and the old style re-installed. In fact it was a fine example of the high cost of puddling. A record of six months is as follows:

COST SHEET, ROANE IRON COMPANY,
CHATTANOOGA, TENN., 1873.

SIX MONTHS OPERATION OF DANKS' PATENT REVOLVING PUDDLING FURNACE.

Tons.	Items of Cost.	Total Cost.	Cost per Ton of Muck Bar
1835.27	Pig Iron — $27.50	$50,469.92	$25.85
954.70	Iron Ore — 9.00	8,592.32	4.40
4148.88	Coal — 3.16	13,110.46	6.72
	Labor, ...	19,552.44	10.02
	Repairs, ...	9,989.46	5.10
1952.41	Muck Bar Produced.......	$101,714.60	$52.09

COAL WASHING MACHINERY.

An important factor in the progress of iron making in the South since the war was the introduction by A. M. Shook and myself in 1890 of the Robinson coal washing machine, a new English patent at the time, which was for several years almost universally used by various furnace companies of the South. This machine has now been largely replaced by the various types of jig washers, but is still in use at our plant at Rockwood with excellent results.

It is unnecessary with this audience to go into details, but I feel justified in saying that with Southern coals it would have been impossible to compete with Northern iron in the early days without this machine, as at that time there was nothing on the market to compare with it in efficiency. Many of these machines were used in the North. The Cambria Iron Company had four or six of them at their works at Johnstown.

A SUCCESSFUL IRON ROLLING MILL.

While it may seem somewhat personal, yet it is only fair to say a word with reference to the Knoxville Iron Company which, in its way, has been a very considerable factor in Southern iron manufacture. This mill, as before stated, was leased by me as Quartermaster under General Ambrose E. Burnside in 1863, and operated until the war closed in 1865, then leased by myself and L. C. Shepperd who afterward sold out to the Richards Brothers, of Pottsville, Pa. It was operated until 1868 as Chamberlain-Richards Com-

pany, when a charter was obtained as the Knoxville Iron Company, and under that name has been operated ever since as a successful enterprise.

At that time there was a great demand for nails so we tried band iron cut across the grain, as the mill was not strong enough to make anything wider than four inches. This answered for a time and the nails did not break if handled with care, but we soon put in a heavier mill,—made twelve inch plate, put in 42 machines, and manufactured cut nails until the wire nails drove us out of the market. This was a good money making enterprise, but it had to go.

The Knoxville Iron Company, which has been in continuous operation for fifty-one years, is the only iron bar mill in the south, and its output is about 50,000 tons per annum. I do not mention the other iron bar manufacturers in the South outside of the Knoxville Iron Company of whom at different dates there have been several, as they have all disappeared, proving unprofitable as most of them have in the North.

Speaking of the red fossil ores of Tennessee, similar to those of Birmingham, there are in the State six stacks, of which only two are now in operation, using these ores and it is not probable that more will be built. Unquestionably, the Birmingham District is more favored in the way of cheap ore and fuel than any other portion of the South and will in all probability hold its present lead. While the Birmingham District has had a very checkered experience it seems now to be on safe ground and I congratulate the courageous and devoted men who have through perseverance and skill been instrumental in bringing this about. (Applause.)

IMPROMPTU REMARKS IN RESPONSE TO CALL OF JUDGE GARY

Judge Gary: Gentlemen, there are nine more speakers on the program, and it is now a quarter of twelve. If they speak ten minutes each, it will be half-past one when we finish, and if they speak five minutes each, it will be half-past twelve. So I am going to ask these speakers to be very brief. And you who are called on must take your chances on keeping these gentlemen here until you get through.

First I will call on Mr. Leopold E. Block, Vice-President of the Inland Steel Company, Chicago.

Mr. Block: Judge Gary and Gentlemen: I promise to be very brief. We have often heard that there is nothing new under the sun. While that may be in some ways true, we have in our time and generation witnessed so very many new and miraculous achievements that we have reached the point where we cease to wonder at the accomplishment of things that we had previously regarded as impossible.

As boys we enjoyed the wide range of imagination indulged in by Jules Verne. Yet many of those things which occurred to him in his wildest flights of imagination seem now to have materialized. The point I want to make is this: I have heard a great deal with regard to the possibilities offered the business men of this country of taking advantage of the conditions and opportunities that the terrible conflict being waged by so many of the nations of the world offers. I venture to say, in view of past performances, that the men of this country will rise to the occasion and by their efforts will bring about the conditions that are justified by the opportunities now presented.

I am reminded of a story, one of a group of stories which have come along with the great success of the Ford Motor Car Company. It seems that Mr. Ford was addressing a large gathering of his agents. In the course of his remarks he stated that they had wonderful cars, in which they used

only high-grade material, and that they had an excellent selling organization. With pardonable pride he declared that one of their fine cars was produced every two minutes, and urged that salesmanship should measure up to production. One of the agents from the rural districts, who was in the rear of the gathering, called out: "That ain't enough!" Mr. Ford seemed to be somewhat astonished, and asked the gentleman if he was to understand that in the judgment of the agent the production of one of their fine cars every two minutes was not enough, and the man answered, "Yes; that ain't enough. There's a sucker born every minute." (Laughter and applause.)

Well, I am not trying to emphasize the birth rate of the men easily parted with their money, but I do want to say that while giving due consideration to all the discussion of the opportunities and the legislation prepared by Congress, it will mean a great deal more to get results. And the opportunities offered "Ain't enough." (Applause.)

President Gary: I will now call on Mr. Edward M. Hagar, President of the Universal Portland Cement Company, Chicago.

Mr. Hagar: Mr. Chairman and Gentlemen: I had a message for this goodly company from a man in the steel industry, but I cannot deliver it in five minutes. I know that the gavel would fall before I could complete my message, so I will simply tell you a story of an Englishman who was "touring" the city of Washington. Looking over the Capitol, his eyes gazing up at the stately dome, he tripped and started to slide down that long flight of steps to the west of the building. When he had slid part of the way down he overtook a rather pretty girl. His feet struck her just above the ankles and she fell back into his lap. To prevent her from falling sideways, he put his arm around her, and together they slid to the sidewalk below. When they had arrived there she made no move to get up, so he said to her, "My dear young lady, this is as far as I go." (Laughter and applause.)

President Gary: Mr. Alvin I. Findley, editor of the *Iron Age*, New York.

Mr. Findley: These interesting—yes, fascinating—recitals by Mr. Bowron and Captain Chamberlain are worth to us all the time that has been devoted to them and more. At one o'clock in the morning, New York time, I feel that a man who has an editorial whack at this audience fifty-two times every year has few rights on this floor, and any speech I may have had in mind is going to wait. This is Veterans' Night. All honor to the men of vision and venture whose courage laid the foundations of iron-making in Alabama, though many of them were denied a part in the fulfillment of their long-deferred hopes. (Applause.)

President Gary: Mr. Richard H. Edmonds, editor of the *Manufacturers' Record*, Baltimore, Maryland.

Mr. Edmonds: It may be interesting to you to know, as you travel over Red Mountain to-morrow and note the great quantity of ore there, that in 1857 Abram S. Hewitt took an option on all that land for $25,000. Mr. Hewitt fully intended to transfer his iron-making activities to this great district. But he saw the coming of the war, and that war, of which we are now getting in Europe just a little illustration, explains why the South is only to-day catching step with the world, and why you see the South so backward as compared with the North and the West. The losses of billions of capital and unspeakable losses of representative men and of consequent power for generations to come—for on the balance sheets of nations as well as on heaven's books men count for far more than even coal and iron—all these terrible losses the South suffered.

For four long years the South bore a struggle relatively, as compared to men and money, just as great as Europe is bearing to-day. On the battle-field, and in the deaths and disabilities that followed the battle-field, it lost about 10 per cent. of its entire white population. After the war, between 1865 and 1900, by reason of the conditions then existing of

poverty and ruin here, such poverty and ruin as we shall see in Europe, the old South lost 5,000,000 people by emigration. From the territory between the Potomac and the Mississippi, 3,500,000 people went entirely beyond the borders of the South, and 1,500,000 more went out into Texas. If you imagine that during the present war, Germany, as one of those that must bear that burden, shall lose on the battle-field 6,000,000 men, and shall in the following thirty-five years lose 40,000,000 or 50,000,000 by emigration, you will get something of a conception of the fearful loss the South sustained.

Yet, to-day, the South, laboring under these conditions, has reached the point where it is mining twice as much coal as the United States mined in 1860. It is making almost exactly the same amount of pig iron as the entire country then produced. It has in its national and state banks and its trust companies $200,000,000 more capital than all the banks of the United States had in 1880. And last year the South spent $90,000,000 in the maintenance of public schools, $12,000,000 more than the United States spent in 1880. (Applause.)

President Gary: Mr. John A. Penton, publisher of the *Iron Trade Review*, Cleveland, Ohio.

Mr. Penton: It has been my good fortune and pleasure to attend a number of the gatherings of this organization in this and other cities, and I think perhaps this meeting will make a record, in some ways if not in many ways, as being the most enjoyable of all.

In the address of our President this morning, and in some things Mr. Bowron said, I have been very much interested, especially in their intimations that there has been a great deal of change in the sentiment of the country towards business. I think that fact is one of the most encouraging notes that we can find in what we observe in reference to the business situation. I sometimes think that perhaps the iron and steel interests of America are somewhat responsible for the attitude of the country, from the fact

that we have not taken occasion to furnish certain information on which the country could base intelligent judgment.

I will just tell you of an incident as an illustration. Some time ago I was talking to a man who told me that his son had come home from Cornell University for a little vacation, and I believe the gentleman is now present. The young man said, "I want to engage in some other business than the steel business." When asked why, he said, "Because they talk so much about it down at school." This incident, typical of many that might be given, seems to show that it is high time that we should make ourselves felt in this connection, and set the country right, for its own sake as well as theirs, concerning the magnificent specimens of American manhood at the head of the iron and steel business of the country; men who are among the country's most upright, fair-minded, level-headed builders. Another gentleman, who was talking about the filing of some indictments against him and some of the industries with which he was connected, said he had been working all his life to make his living, and working for the success of the industry with which he had been connected, and these unfounded charges have been a source of much mental suffering to him. He added that he hoped some time this American Iron and Steel Institute would take an outspoken stand in behalf of its members and of the employees and the stockholders of the companies represented in its membership. (Applause.)

President Gary: We shall now hear from Mr. Joseph G. Butler, Jr., Vice-President of the Brier Hill Steel Company, Youngstown, Ohio. Uncle Joe. (Applause.)

Mr. Butler: This obstruction in front of me reminds me of a story. A board of trustees in one of our numerous churches in Youngstown was considering various improvements. At a meeting one night, among other things which came up for action was the installation in the church of a candelabrum. I don't know why they did not take this one away from in front of me, especially when the pho-

tographer was here. (Laughter.) After the discussion of this matter, a friend of mine on the board said, "Well, of course I will vote for this candelabrum; but after you get it who is going to play on it?" (Laughter.)

You will remember that at the last meeting of the Institute held in New York, the evening program provided, as usual, for impromptu speeches on the call of Judge Gary. I had carefully prepared one, as Mr. King and Mr. Campbell are in the habit of doing. I had planned to go home that night, and I told Mr. McCleary that I would take the eleven-thirty train, the last train out of New York for the Pittsburgh and Youngstown district. After the Judge had called on eight or nine others and had discovered I had gone, he announced that he would like to hear from Uncle Joe. (Laughter.) Therefore, for the first time in the history of the American Iron and Steel Institute, and I might incidentally say the same in reference to the Gary dinners, I was overlooked. So I am very glad to know that they think enough of me to call upon me to-night to make an impromptu speech. And this really is one. (Laughter.)

We came on the "slow train from Cleveland" yesterday. We boarded the train at Youngstown at nine-fifty yesterday afternoon. Just as the train was pulling out a reporter on one of the local papers hurried up and said, "Mr. Butler, are any of you people going to speak at the Institute dinner in Birmingham?" I says, "Sure, Mr. Campbell always speaks." "Oh, that is all right," said the reporter, "I have got his speech, and that's going to be in to-night's paper." (Laughter.)

Now, speaking seriously, and with the candelabrum still in front of me, this is not the first time that I have been in Birmingham. In 1890 the iron and steel manufacturers of the United States entertained the Iron and Steel Institute of Great Britain, which then, as now, included a number of the iron and steel manufacturers of the continent. The American Iron and Steel Institute had not yet been organized, but the American Institute of Mining Engineers took charge of the matter, and it was a great event. There were five special trains, and Mr. Kirchhoff, whose name has been

mentioned here, had more or less to do with it. He was at that time the editor of the *Iron Age*. We came to Birmingham, and I remember distinctly our reception here. We had a genuine exhibition of Southern hospitality, just as we had this afternoon. Some of the trains went to the Lake Superior region and other parts of the country.

I was placed in charge of a train, and it may surprise you to know that under me was Andrew Carnegie! Just think of his being under anybody. He was one of the subcommittee I was on, but I was the head of it and he was under me. (Laughter.) Mr. Carnegie is respected and loved by everybody. He is trying to get rid of his accumulated wealth, and I think he is succeeding very well. We are helping him out at Youngstown. (Laughter.) I understand that he gave fifty thousand dollars for a library there without any restrictions, and he said if we wanted anything else he would have it put there. (Applause.)

This afternoon I went over to this—I have forgotten how Mr. McCleary pronounced it; I think it was "tay dansant," or something like that. Anyway it was the curtain-raiser to what we may expect before we leave Birmingham. While I was over there, I said to the young ladies, and to some middle-aged ladies, and incidentally to one old lady, that my time for dancing was past, that I was too old to dance or even to have rheumatism. "However," I said, "maybe I will take it under advisement, and some time when I come back to Birmingham I will learn these new steps." I made engagements with I don't know how many young ladies to appear at the Country Club to-morrow night, and I hope they won't forget it, either. (Laughter.)

Now when I was here with Mr. Corey and his party five or six years ago, we tried diligently, and Mr. Crawford and Mr. Dinkey and some others helped me—two Mr. Crawfords, because there was Mr. Webb Crawford, one of my truest friends in Birmingham. They worked hard trying to find somebody that remembered that I was here in 1890. Finally they discovered one old gentleman who remembered indistinctly; he didn't remember me very clearly.

He said, "I think I do remember your being here in 1890. I think Mr. Carnegie was here at the same time, and there was a banquet." "What is the particular thing," I asked, "that makes you remember that I was here?" He answered, "I think you sat next to Mr. Carnegie, and I remember your asking for the second helping of soup." (Laughter.)

Before I left home on this trip I inquired about Birmingham being dry. I says, "I am told Birmingham is dry, and if that is the case I am not going." We are pretty dry at Youngstown, so dry that some of our people won't even drink water. (Laughter.) They told me that things had been fixed in Birmingham so that I could have some of this stuff here, and I says, "All right, I will come," and I am here. (Laughter.)

I want to say just a word—speaking seriously once more; I was very, very much impressed with Judge Gary's address this morning. (Applause.) I am proud to say that I have not missed a single meeting of the American Iron and Steel Institute, and I have heard other addresses that Judge Gary has made. Our train was late this morning, and I asked the conductor what time we would get here. He said they would get us here about half-past ten o'clock, and I thought perhaps we would be a little late for the opening session, but they were kind enough to wait for us. I was very much impressed with what Judge Gary said. I have heard him on many occasions, but never before did I listen to him with such serious satisfaction as to-day. And I hope what he said will be published and given wide distribution, for I cannot think of anything that would do more good than to have his address of this morning widely distributed over the country. (Applause.)

I suppose my five minutes is about up. I heard of an Irishman once that was telling about the troubles of Ireland. He said the cup of misery had overflowed, but was not quite full yet. And I feel a little that way. My cup of joy has overflowed, but there is a little left here yet. I feel very much pleased with this trip to the South, and I am going to stay until—to use a slang phrase—until the last

dog is gone. They tell me that they have changed the plans and are going to stay here until the 15th of November, and I am here with you. I haven't looked at my mail. I don't know what all I am going to be invited to, but I am going to attend everything I am asked to attend, and perhaps some things that are not on the program. (Laughter and applause.)

President Gary: Mr. James A. Farrell, President of the United States Steel Corporation, New York.

Mr. Farrell: It is a matter for gratification that we have been able to hold this meeting in the city of Birmingham. There are few instances in history of a city increasing in population from 38,000 to 133,000 in a decade, as Birmingham did between 1900 and 1910. The city now has probably a population of nearly 200,000.

This is the first meeting of the Institute to be held in the South, which section contributes so largely to our international trade. Last year the value of the cotton exports of this country was twice that of our exports of iron and steel.

The facilities offered under the federal reserve act in permitting discount privileges to foreign paper and the establishment abroad of branches of national banks will redound to the advantage of the domestic and export interests of the South, as one of the few difficulties still remaining to be overcome in the extension of foreign trade is the question of finance and credit. The South is more largely concerned with respect to our foreign commerce than any other section of the country, due to the necessity of keeping open its foreign avenues of commerce for its cotton, lumber, phosphate rock, sulphur, iron and steel and a hundred other commodities. The canal has opened wide the doors of opportunity for the South to the possibilities on the western coast of South America and Central America, and also to our western States and British Columbia.

In considering this position of the South as a factor in the commerce of the world, many members of this Institute will naturally think in terms of profound sympathy for our

brethren in the European steel industry now engaged in what seems to us, in view of our former close friendship with them and theirs with each other, a fratricidal struggle. The great calamity of this war, and its evil effect upon ourselves in common with every other nation of the world, is made almost personal to us in contemplation of what it means to the steel industry of Europe and our friends in that industry, who by their visits to this country and our visits to them have, for many years, cemented the ties of friendship.

The first three months of this war, which all of us hope will not be greatly prolonged, have demonstrated that we are confronted by conditions never before imagined, and that it is necessary to consider new methods of conducting business along lines in which there has been, in our lifetime, no precedent. That chaotic business conditions resulted immediately from such a cataclysm of destruction of property, of the dislocation of the world's commerce, has not been surprising; that the United States has not suffered more, that we have been enabled to maintain confidence in the stability of our institutions and in the ultimate recovery to normal conditions, is a matter of congratulation.

That buying in many lines has been contracted to cover only immediate needs has perhaps been natural; but if reports from numerous centers of consumption may be credited, many warehouses are comparatively bare of supplies—retrenchment has been overdone. And with the cordial cooperation of the various departments of the government in devising measures to assist in financing the cotton crop and providing suitable financial machinery, with the influx of demand for materials for foreign consumption, many of which have never before been exported in such large quantities from this country, with the exercise of the ingenuity of our people in manufacturing for our own consumption articles heretofore imported from abroad and thereby giving employment in new lines of industry, it may be not only reasonably hoped but with assurance expected that with the beginning of a new year a new era of expanding business will dawn. (Applause.)

President Gary: Mr. Willis L. King, Vice-President of the Jones and Laughlin Steel Company, Pittsburgh, Pa.

Mr. King: Mr. Chairman, owing to the lateness of the hour, I would ask that you excuse me from saying anything, except that I feel that I must take advantage of this opportunity to express my personal appreciation of the hospitality and kindness of the good people of Birmingham to the self-invited strangers within their gates, the members of the American Iron and Steel Institute, holding their first meeting in the South. This hospitable reception has been very charming, but not altogether unexpected. When the directors were considering the location for the October meeting of the Institute, some doubt was expressed about the wisdom of holding it at Birmingham. Judge Gary declared that there were more lovely ladies and gracious hospitality in Birmingham than in any other place within his knowledge. That settled the matter, and here we are. (Applause.)

The large attendance amply justifies the selection. And this well-attended meeting should be regarded by our Southern members both as evidence of the importance of this district in the steel industry and as an expression of the Institute's good-will, and its hearty wishes for the continued growth and prosperity of this city and section.

The whole nation sympathizes with the South in the unfortunate condition of the market for their great staple. I wish I could, even in a small measure, dispel some of the dark shadows now hanging over them. That the way will be found I have no doubt, for our people have never yet failed in an emergency. I beg our Southern friends to remember that there can be no shadow without light, and that light cometh in the morning. (Applause.)

President Gary: Mr. George Gordon Crawford, President of the Tennessee Coal, Iron and Railroad Company of this city, will close the informal speaking of the evening. Mr. Crawford. (Applause.)

MR. CRAWFORD: Mr. Chairman, the Birmingham members of the American Iron and Steel Institute, located at this distant outpost of iron and steel manufacture, are seldom honored by a visit from their comrades in the industry, and they are deeply appreciative of this visit.

We do not believe that you have undertaken this long and tiresome journey entirely to read and discuss the excellent papers that we have heard to-day, or to participate in this banquet, because many facilities for holding your meetings are nearer your homes. We assume, therefore, that the object of your visit was partly to see this industrial district, and on Friday and Saturday we hope to afford you adequate opportunities for seeing it.

But we hope that you will not confine your attention entirely to the industrial district. Mr. Hoerr, who discussed a paper this morning on the steam turbine, in a discussion or lecture before his fellow engineers in Pittsburgh some time ago accused them of confining their attention to the study of the laws of nature to the exclusion of the laws of human nature.

We hope the members of the Institute are going to take advantage of the facilities which will be provided for Saturday afternoon for seeing something of this district other than the industrial district—the residence districts of Birmingham and Fairfield. There are in this town a lot of human, likable people; and if you stay here long enough for them to know you they will see to it that your hours pass pleasantly. (Applause.)

JUDGE GARY: In behalf of the directors of the Institute, I thank you gentlemen who have prepared and presented the splendid addresses during the day. Also I thank the members of the Institute who have come a long distance to this beautiful place for the purpose of showing their loyalty to the Institute and their appreciation of this great and growing section of our country.

I bid you good-night. (Great applause.)

SOME OF THE HOSPITALITIES ENJOYED AT THE BIRMINGHAM MEETING

From experience at previous meetings, the members of the Institute anticipated an interesting and instructive set of papers and discussions, and their expectations were fully met. The fact that the meeting was to be held in the South suggested the proverbial hospitality of that section, and in this respect those who attended the meeting found their anticipations more than realized.

Expecting an enjoyable time, a number of the members brought their wives with them. Learning this, the officers of the Southern Club arranged for a Thé Dansant on Thursday afternoon at four o'clock, inviting not only the ladies but also the gentlemen of the Institute. As Mr. Butler remarked in his impromptu speech at the Institute dinner, this was "the curtain raiser" to Birmingham's hospitalities.

On Friday forenoon and afternoon and on Saturday forenoon, the members of the Institute were the guests of the Tennessee Coal, Iron and Railroad Company, visiting by special train many of the principal mines and mills in the Birmingham district. On the opening day of the meeting the company had distributed among the members a beautifully printed booklet entitled "A Little Journey in the Birmingham District." This booklet gave, with attractive illustrations, just the kind of information that the members of the Institute needed in order to appreciate and enjoy the proposed trip. Indeed, after using the booklet as a pocket guide most of the members took it home as an interesting and useful souvenir.

The itinerary of the trip had been mapped out with remarkable foresight. It afforded ample time for visiting each of the plants. Without hurry and without waste of time, the party was able to keep exactly on the schedule. The itinerary was as follows:

FRIDAY, OCTOBER 30, 1914.

Lv. Birmingham (L. & N. R. R. Station)	Via L. & N. R. R.		9:15 A. M.
Ar. Ishkooda (Mine No. 13)	"	"	10:00 "
Lv. Ishkooda	"	"	10:30 "
Ar. Woodward Junction	"	"	10:45 "
Ar. Woodward (W. I. Co. Fces.)	"	W. I. Co. R. R.	10:55 "
Lv. "	"	B. S. R. R.	11:30 "
Ar. Bayview	"	"	12:15 P. M.

BARBECUE SERVED.

Lv. Bayview	Via B. S. R. R.		1:15 P. M.
Ar. Edgewater (Edgewater Mine)	"	"	1:25 "
Lv. "	"	"	1:55 "
Ar. Fairfield (T. C. I. By-Product Plant)	"	"	2:15 "
Lv. " " " "	"	"	2:40 "
Ar. " (Am. Steel & Wire Plant)	"	"	3:00 "
Lv. " " " "	"	"	3:45 "
Ar. Birmingham (L. & N. R. R. Station)	"	"	4:30 "

SATURDAY, OCTOBER 31, 1914.

Lv. Birmingham (L. & N. R. R. Station)	Via B. S. R. R.		9:15 A. M.
Ar. Thomas (Republic I. & S. Co. Fces.)	"	"	9:30 "
Lv. Thomas	"	"	10:00 "
Ar. Ensley (East End Furnace Plant)	"	"	10:20 "
Lv. West End Furnace Plant	"	"	11:05 "
Ar. Open Hearth	"	"	11:15 "
Ar. Rail Mill Finishing Department	(Walk)		11:40 "
Ar. Rail Mill	"		11:55 "
Ar. Turbo Station	"		12:15 P. M.
Lv. Ensley Turbo Station	Via B. S. R. R.		12:30 "
Ar. Birmingham (L. & N. R. R. Station)	"	"	1:00 "

About thirty well-informed Birmingham gentlemen acted as guides. The members of the Institute were divided into groups of ten, each group having its own guide.

During the noon hour a barbecue lunch was served at Bayview. As the barbecue is a Southern institution and most of the members were from the North, the method of preparing the barbecue was in itself of interest. During the meal one of the six bands of the Tennessee Coal, Iron and Railroad Company played.

On Friday evening the members of the Institute and their wives were guests at a reception given by the Country Club, whose beautiful and commodious club house, situated in the South Highlands about a mile from the Tutwiler Hotel, was gay with music and dancing until long after midnight.

On Saturday afternoon the Chamber of Commerce took a large number of members in automobiles through the residential sections of Birmingham, known as North Highlands and South Highlands. As the names indicate, these portions of the city occupy high land—the elevation being from 700 to 1,000 feet above sea level—and enjoy a very equable temperature, ranging from an average of 46° in winter to 81° in summer. In these residential sections, built upon the sides of Red Mountain and overlooking the city and the surrounding country, the streets are so planned as to conform to the surface of the ground, running not in straight lines but in curves, thus preserving the beauty of the landscape. As one rides along these streets the vista constantly changes. The grounds around the residences are tastefully laid out, natural beauties being preserved so far as practicable. These residential sections are very extensive and of rare beauty. Birmingham justly prides itself on being "a good place to live in."

The Country Club and the Roebuck Springs Automobile and Golf Club extended invitations to the Institute to use their fine golf courses, and quite a number of the members availed themselves of these courtesies.

It is the unanimous verdict of those who attended the meeting that it was one of the most profitable and enjoyable meetings that the Institute has ever held, many declaring it "the best ever." All are enthusiastic over the great resources of the Birmingham district, over the imposing business structures of the city, over its beautiful residential sections, but most of all over the warm-hearted hospitality of its people.

PARTICIPANTS—MAY MEETING

Abbott, F. E.
Abell, O. J.
Ahles, R. L.
Allen, E. M.
Allen, James P.
Amaden, Edwin A.
Andrews, Jay I.
Armour, M. Cochrane
Armstrong, Eliot
Atwater, Christopher G.

Baackes, F.
Bacon, C. J.
Bailey, Edward
Bailey, William M.
Baldridge, W. H.
Baldwin, H. G.
Balsinger, W. R.
Banks, A. F.
Barbour, H. H.
Barren, H. A.
Beale, A. H.
Beaumont, George H.
Bennett, C. W.
Bentley, F. T.
Bever, John J.
Blauvelt, W. H.
Boley, Ernst
Bonner, James B.
Booth, C. M.
Boutwell, Roland H.
Bowen, A. P.
Bowler, R. P.
Bowman, L. H.
Boynton, A. J.
Brainard, J. W.
Braine, D. L.
Braine, L. F.
Braman, H. S.
Brassert, H. A.
Breeden, William
Brooks, J. J., Jr.
Browne, De Courcey
Buck, C. A.
Budd, R. B.
Buek, C. E.
Buffington, Eugene J.
Burdick, W. P.
Burr, F. A.
Burry, James
Bush, D. Fairfax
Bush, H. D.
Butler, Joseph G., Jr.

Camp, J. M.
Campbell, J. A.
Campbell, L. J.
Carhart, P. E.
Carnahan, R. B.
Carr, R. B.
Carse, David B.
Carse, John B.
Catchings, Waddill
Chamberlain, Hiram S.
Chauvenet, S. H.
Christie, M. G.
Clark, Eugene B.
Clark, John B.
Clark, R. W.
Clarke, A. F.
Clarke, E. A. S.
Clarke, Thomas C.
Clopper, H. G.
Close, Charles L.
Cluff, Charles C.
Coles, T. B.
Connell, Frederick
Cook, Edgar S.
Cook, H. H.
Cooke, D. W.
Coons, P. T.
Cooper, G. M.
Corbett, Willeby T.
Cordes, Frank
Corne, W. E.
Coulby, Harry
Crabtree, F.
Cragin, George A.
Crane, T. I.
Crawford, E. R.
Crawford, George G.
Crawford, W. D.
Crispin, M. Jackson
Croft, H. W.
Crook, Alfred
Croxton, D. T.
Cuntz, W. C.

Dailey, C. I.
Damerel, George
Darlington, Thomas
Davidson, John M.
Davies, George C.
Davis, Charles C.
Davis, Henry J.
Davis, W. O.
Dean, William T.
Decker, Omar S.
Deericks, Joseph G.
DeForest, A. T.
Deming, Fred C.
Dette, William
Devens, H. F.
Devlin, Thomas
Dewey, Bradley
Diehl, A. N.
Dietrich, L. A.
Dillon, A. H.
Dodd, A. W.
Donner, W. H.
Dougherty, J. W.
Draper, Trusten P.
Driscoll, Daniel J.
Duncan, John
Du Puy, Herbert
Dyer, Philip S.

Edmonds, Richard H.
Edwards, J. H.
Elverson, J. S.

Farrell, James A.
Farrell, W. H.
Fedder, W. P.
Felton, Edgar C.

Field, William A.
Filbert, W. J.
Findley, A. I.
Finley, J. B.
Fitzpatrick, F. F.
Floersheim, Berthold
Follansbee, William U.
Forbes, W. A.
Fowler, A. A.
Francis, L. W.
Frank, Isaac W.
Froment, E. McK.
Fuller, H. A.
Fuller, Willard

Gage, Fred E.
Gary, Elbert H.
Gayley, James
Geddis, Robert
Gedge, Frederick C.
Gerry, Roland
Gleason, W. P.
Glenn, Thomas K.
Gordon, F. H.
Grace, E. G.
Graham, Charles J.
Gray, J. H.
Gray, L. J.
Gray, Wm. G.
Gresham, W. B.
Griffiths, E. S.
Grugan, Justice

Hackett, S. E.
Hagar, Edward M.
Hagar, G. A.
Hall, R. S.
Hamilton, John W.
Hammond, James H.
Hanna, M. A.
Hansell, N. V.
Harris, W. A.
Harrison, H. T.
Hartshorne, Joseph
Hatfield, Joshua A.
Heckscher, A.
Hewitt, G. W.
Hickok, Charles N.
Higgins, H. E.
Hildrup, W. T., Jr.
Hill, William H.
Hirschland, F. H.
Hobson, Robert
Hodgkinson, Francis
Holmes, C. O.
Horner, W. S.
Hovey, Otis E.
Howe, F. P.
Howe, Henry M.
Hoyt, Elton, 2d
Hoyt, J. H.
Hubbard, P. H.
Hughes, H. L.
Hughes, I. Lamont
Hughes, John
Hurd, Charles S.
Huston, A. F.
Hutchinson, O. N.
Hyatt, W. E.

Ingraham, F.
Ireland, R. L.
Irons, Robert H.
Isham, Phillips
Ives, Edward L.

James, Henry L.
Jarecki, Alexander
Jay, John C., Jr.
Jewell, William E.
Jewett, George W.
Johnson, Frank H.
Johnson, J. E., Jr.
Johnson, Lewis
Johnston, Archibald
Johnston, C. T.
Jones, Evan F.
Jones, Harry R.
Jones, Henry L.

Keefe, J. S.
Kennedy, Frank G., Jr.
Kennedy, Hugh
Kennedy, J. J.
Kennedy, T. W.
Ker, S. P.
Kerr, D. G.
Keyes, F. A.
King, Willis L.
Knowles, Morris
Knox, L. L.
Koppers, Heinrich
Kreitter, J. W.
Kreps, J. E.

Lamont, R. P.
Lanahan, Frank J.
Langenbach, Edward A.
Larkin, J. K.
Larsson, Emil
Lee, L.
Leet, George K.
Leonard, William A.
Lessig, J. B.
Lewis, J. E.
Lippincott, James
Lovejoy, Frederick B.
Luckie, R. R.
Lukens, William W.
Lustenberger, L. C.

McAlarney, John H.
McCleary, Elmer T.
McCleary, J. T.
McCormick, S. L.
McCrea, Archibald M.
McCurdy, Sidney
McElhany, C. B.
McGowan, C. L.
McIlvain, Edward M.
McKay, George F.
McKay, Richard V.
McKee, Arthur G.
McKee, W. C.
McKenna, A. G.
McLaughlin, William
McLeod, John
McMahon, R. E.
McMurray, Max
McMurtry, Geo. G.
MacDonald, Duncan C.
Mack, A. F.
Major, Charles
Major, S. T.
Marshall, C. D.
Marshall, C. S.
Marshall, S. M.
Mather, Amasa Stone
Mather, S. L.
Mathews, John A.

Mathias, David S.
Meaker, J. W.
Meissner, Carl A.
Mercur, Robert J.
Meredith, W. F.
Merriman, D. A.
Mesta, George
Meyers, Frederick
Miller, C. D. S.
Miller, C. F. Huston
Morgan, W. H.
Molleson, George E.
Morris, A. F.
Morris, L. B.
Moss, John B.
Mudge, E. W.
Mulliken, Alfred H.
Murray, Montgomery
Murray, Thomas

Nagle, L. F.
Nash, A. L.
Nash, H. P.
Neeland, M. A.
Ney, Robert W.
Nichols, J. A.
Nicoll, Benjamin
Niedringhaus, G. W.
Niemann, C. F.
Noland, Loyd
Nullmeyer, Frank H.

Orrock, G. A.

Palmer, William P.
Palmer, William R.
Parrish, R. L.
Peckitt, Leonard
Penton, John A.
Perin, C. P.
Perley, W. B.
Peters, Richard, Jr.
Petinot, N.
Pew, John O.
Pilling, G. P.
Pilling, W. S.
Plummer, J. H.
Potter, W. S.
Pratt, R. H.
Prendergast, G. A.
Preston, Veryl

Quarrie, B. D.

Rachals, Walter
Ralston, Joseph S.
Rand, Charles F.
Reese, John N.
Reilly, W. C.
Reinhardt, G. A.
Reis, John
Replogle, J. L.
Reynders, J. V. W.
Richards, F. B.
Roberts, Frank C.
Robinson, Alexander P.
Robinson, Cyrus
Robinson, C. S.
Robinson, T. W.
Roe, James P.
Ross, Lewis P.
Rowe, Wallace H.
Ruhl, Louis
Ruiloba, J. A.
Rust, Henry B.
Rust, W. F.
Ryerson, E. L., Jr.

Samuel, Frank
Satler, Charles E.
Sauveur, Albert
Savage, H. D.
Scammell, M. J.
Schiller, W. B.
Schleiter, W. F.
Schmidt, John C.
Schonthal, Dez. C.
Schuster, W.
Schwab, Charles M.
Seaver, Kenneth
Sells, G. W.
Sheadle, J. H.
Sherer, J. Norman
Sherman, Wm. O'Neill
Shimer, George S.
Shiras, MacGilvray
Shover, B. R.
Sias, John M.
Sim, James
Simpers, Thomas W.
Slick, E. E.
Smith, C. C.
Smith, J. W.
Snyder, W. E.
Souder, Harrison
Stambaugh, John
Stanton, W. A.
Stark, C. J.
Stearns, Edward B.
Steese, R. C.
Stevens, Charles G.
Stevens, H. L.
Stevenson, A. A.
Stillman, J. S.
Stone, E. E.
Sturdevant, Charles R.
Sullivan, George M.
Sullivan, W. J.
Suppes, Max M.
Sweetser, R. H.

Taylor, B. H.
Taylor, Knox
Taylor, T. H.
Taylor, Wade A.
Thomas, Charles S.
Thomas, E. P.
Thomas, Leon E.
Thomas, W. A.
Thorp, George G.
Thropp, J. Earlston, Jr.
Timmins, George
Tinsley, John F.
Topping, John A.
Townsend, J. Fred

Unger, John S.

Verity, G. M.
Vogel, F. A.
Vogt, C. A.

Waddell, J. D.
Wadsworth, J. E.
Walker, J. C.
Walker, William H.
Walker, W. R.
Wallace, James C.

Ward, James H.
Waterhouse, G. B.
Watson, John J.
Wayland-Smith, R.
Webster, Wm. R.
Weld, C. M.
Wells, R. G.
Wendell, Carl A.
West, Arthur
Westfall, H. D.
Wheeler, Andrew
Wheeler, C. V.
White, George A.
Whyte, George S.
Wilkinson, H. S.
Williams, F. B.
Williams, H. D.
Wilmot, Frank A.
Wilputte, Louis
Winckler, Elmer E.
Witherbee, F. S.
Wolfe, William Lloyd
Wood, Richard G.
Woodard, L. A.
Woods, John E.
Woods, Leonard G.
Worth, E. H.
Worth, W. P.
Wright, P. E.
Wright, W. L.

PARTICIPANTS—OCTOBER MEETING

Aldrich, T. H.
Allen, Anson W.
Andrews, J. I.
Armour, M. C.
Atwater, C. G.

Baackes, F.
Bachman, F. E.
Bailey, R. W.
Baker, George
Baldridge, W. H.
Baldwin, H. G.
Ball, Edwin
Banks, A. F.
Barnes, Edward M.
Barr, C. J.
Barren, Henry A.
Barren, H. B.
Barringer, D. M.
Battelle, Gordon
Bauer, Charles L.
Beecher, L. T.
Belden, S. B.
Bell, E. H.
Benners, T. H.
Bennett, C. W.
Bever, John J.
Black, Herbert F.
Blanchard, C. M.
Block, L. E.
Bodwell, H. L.
Boland, R. W.
Boley, Ernst
Bonney, J. W.
Bowron, James
Boynton, D. S.
Braman, H. S.
Brassert, H. A.
Bray, T. J.
Brooks, J. J., Jr.
Brown, Fayette
Buek, C. E.
Buffington, E. J.
Burdick, W. P.
Burr, Frank A.
Bush, M. W.
Butler, Joseph G., Jr.

Campbell, J. A.
Campbell, L. J.
Carey, Augustus W.
Carpenter, A. H.
Chamberlain, H. S.
Charls, G. H.
Clarke, E. A. S.
Coakley, J. A.
Coffin, H. W.
Collier, J. Z.
Collier, William E.
Connors, George W.
Cook, Edward B.
Cook, Howard H.
Cornelius, Henry R.
Cornelius, William A.
Coulby, Harry
Crawford, E. R.
Crawford, George G.
Crawford, W. D.
Crockard, Frank H.
Croft, H. W.
Cutler, Frank G.

Dalton, H. G.
Davis, Henry J.
Davis, S. A.
Dilks, Lorenzo C.
Dinkey, A. C.
Dodd, A. W.
Donner, W. H.
Dows, David
Driscoll, Daniel J.

Eagan, J. J.
Edmonds, Richard H.
Edwards, V. E.
Elliott, C. H.
Ellis, E. E.
Elverson, J. S.
Estep, F. L.
Estep, H. Cole
Evans, David
Eynon, D. L.

Fairbairn, C. T.
Faris, Jacob M.
Farrell, James A.
Felton, E. C.
Findley, A. I.
Fletcher, J. F.
Foust, Thomas B.
Fuller, Willard

Gardner, William
Gary, Elbert H.
Gassman, H. M.
Gedge, F. C.
George, Jerome R.
Gleason, William P.
Glenn, Thomas K.
Gordon, P. J.
Greer, H. C.
Griffiths, E. S.
Grose, James H.

Hadley, W. E.
Hagar, Edward M.
Hammond, Horace
Hammond, James H.
Harrison, H. T.
Hatfield, Joshua A.
Hillman, M. P. Gentry
Hoerr, Alexander L.
De Holl, Henry R.
Howard, Clarence H.
Horner, W. S.
Hoyt, Elton, 2nd
Hubbard, J. W.
Hufnagle, F. B.
Hughes, John
Hughes, William H.
Hulst, John
Hutchinson, O. N.

Jacobs, Ward W.
James, Henry L.
Jarecki, A.

Jeffrey, R. H.
Jewell, Thomas M.
Jewett, G. W.

Kagarise, John W.
Kaufholz, C. F.
Keefe, J. S.
Kennedy, T. W.
Kent, J. F.
Kimball, G. C.
King, Willis L.
Kluttz, W. L.
Knowles, Morris

Landgrebe, K.
Leake, W. E.
Lee, Leif
Lees, John W.
Leet, George K.
Lemoine, L. R.
Lewis, John F.
Lilly, Eugene Guy
Llewellyn, Silas J.
Luckie, R. R.
Lutz, Charles W.

McAteer, Howard W.
McCleary, J. T.
McCullough, C. H., Jr.
McDonald, Thomas
McGonagle, W. A.
McGowan, C. L.
McIlvain, E. M.
McKee, Arthur G.
McQueen, James W.
McWane, J. R.
Maben, J. C.
Maben, J. C., Jr.
Mackenzie, George C.
Maeder, C. E.
Major, Charles
Marshall, C. S.
Marsteller, Orville A.
Mather, S. Livingston
Mathias, David S.
Mathias, T. H.
Mathias, William G.
Meacham, D. B.
Meehan, Augustus F.
Mehlhorn, H. M.
Mesta, C. J.

Mesta, George
Miller, C. L.
Moffett, C. A.
Morgan, E. C.
Morgan, Paul B.
Morris, Frank G.
Moulton, Wallace C.
Mudge, E. W.

Ney, Robert W.
Nibecker, Karl
Nichols, John A.
Noland, Lloyd
Nullmeyer, Frank H.

Palmer, William P.
Pargny, E. W.
Parsons, A. C.
Penhallegon, Will J.
Penton, John A.
Perkins, H. F.
Perley, W. B.
Phipps, Charles R.
Pilling, W. S.
Porch, James W.
Porter, J. W.
Preston, Veryl

Quarrie, B. D.

Rachals, Walter
Radford, Robert
Ramsay, Erksine
Rathbone, R. L.
Reeves, Samuel J.
Reilly, W. C.
Reinhardt, G. A.
Robinson, C. R.
Robinson, C. S.
Robinson, T. W.
Rogers, William A.
Rose, George E.
Ross, Lewis P.
Rust, E. J. L.
Rust, H. B.
Ryding, H. C.

Schonthal, Dez C.
Shannon, W. T.
Sheadle, J. H.
Shilling, W. W.

Shimer, George S.
Shook, J. W.
Shook, Paschal G.
Short, G. W.
Siebert, W. P.
Smith, James W.
Souder, Harrison
Speller, F. N.
Stephenson, James I.
Stewart, H.
Stillman, Charles A.
Stillman, J. S.
Stone, E. E.
Strale, Allan
Swann, Theodore

Taylor, Arthur W.
Taylor, Wade A.
Thomas, Charles S.
Thomas, E. P.
*Thomas, H. Spence
Thomas, W. A.
Thompson, David P.
Thorp, George G.
Tod, Fred
Toulmin, P.
Tutwiler, H.

Unger, J. S.

Vogt, Charles A.
Vreeland, Geo. W.

Waddell, J. D.
Walker, William R.
Wallingford, B. A., Jr.
Waterhouse, G. B.
Weir, E. T.
Wellman, S. T.
Westfall, Harry D.
Whatley, J. W.
Wheeler, Seymour
Wilson, Willard
Winslow, F. B.
Wood, F. W.
Woodard, L. A.
Woodward, A. H.
Wright, H.

Young, Andrew G.

Zehnder, C. H.

* Guest.